Does Sleep Causally affect Stress?

CME Assignment II

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Contents


```
library(readr)
```

```
## Warning: package 'readr' was built under R version 4.2.3
```

1 Research Question

Primary question: Does Sleep Stress Levels of Students? We will study the data collected from various volunteers and analyze the causal relation between sleep an stress.

Hypothesis: Lower hours of sleep and lower sleep quality leads to high stress levels.

The data we use has:

1. Anxiety Level (GAD-7)
2. Self Esteem (Rosenberg Self Esteem Scale)
3. Mental Health History (0-1)
4. Depression(in accordance with PHQ-9)
5. Headache
6. *Sleep Quality* [treatment 1]
7. Basic Needs
8. Blood Pressure(low)
9. Academic Performance
10. Study Load
11. Teacher Student Relationship
12. Future Career Concerns
13. Extra Cirricular Activities
14. Bullying
15. **Stress Level** outcome[]

1.1 What does science say about the correlation of sleep and stress?

Not getting enough sleep can cause a negative mood, low energy, difficulty concentrating, and a general inability to function as usual. Lack of sleep may have severe consequences in some circumstances, such as if a person is driving or operating heavy machinery when tired. The occasional night of poor sleep is unlikely to cause harm, but persistent sleep deprivation can increase the risk of several chronic health conditions.[1]

Research suggests that the relationship between sleep and mental health is complex. While lack of sleep has long been known to be a consequence of many psychiatric conditions, more recent views suggest that lack of sleep can also play a causal role in both the development and maintenance of different mental health problems.[2]

2 DAG Analysis

From our data-set:

```
ssdata <- read_csv("R:/Sem V/Comp Methods For
↪  Econ/Assignment-II/Data/StressLevelDataset.csv")
```

```
## Rows: 1100 Columns: 21
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## dbl (21): anxiety_level, self_esteem, mental_health_history, depression, hea...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
colnames(ssdata) <- tolower(gsub(" ", "_", colnames(ssdata)))
head(ssdata)
```

```
## # A tibble: 6 x 21
##   anxiety_level self_esteem mental_health_history depression headache
##           <dbl>       <dbl>                 <dbl>      <dbl>    <dbl>
## 1            14          20                     0         11        2
## 2            15           8                     1         15        5
## 3            12          18                     1         14        2
## 4            16          12                     1         15        4
## 5            16          28                     0          7        2
## 6            20          13                     1         21        3
## # i 16 more variables: blood_pressure <dbl>, sleep_quality <dbl>,
## #   breathing_problem <dbl>, noise_level <dbl>, living_conditions <dbl>,
## #   safety <dbl>, basic_needs <dbl>, academic_performance <dbl>,
## #   study_load <dbl>, teacher_student_relationship <dbl>,
## #   future_career_concerns <dbl>, social_support <dbl>, peer_pressure <dbl>,
## #   extracurricular_activities <dbl>, bullying <dbl>, stress_level <dbl>
```

2.1 Deciding the DAG edges

```
library(dagitty)
library(ggdag)
```

```
## Warning: package 'ggdag' was built under R version 4.2.3
```

```
##
## Attaching package: 'ggdag'
```

```
## The following object is masked from 'package:stats':
##
##     filter
```

```
library(ggplot2)
```

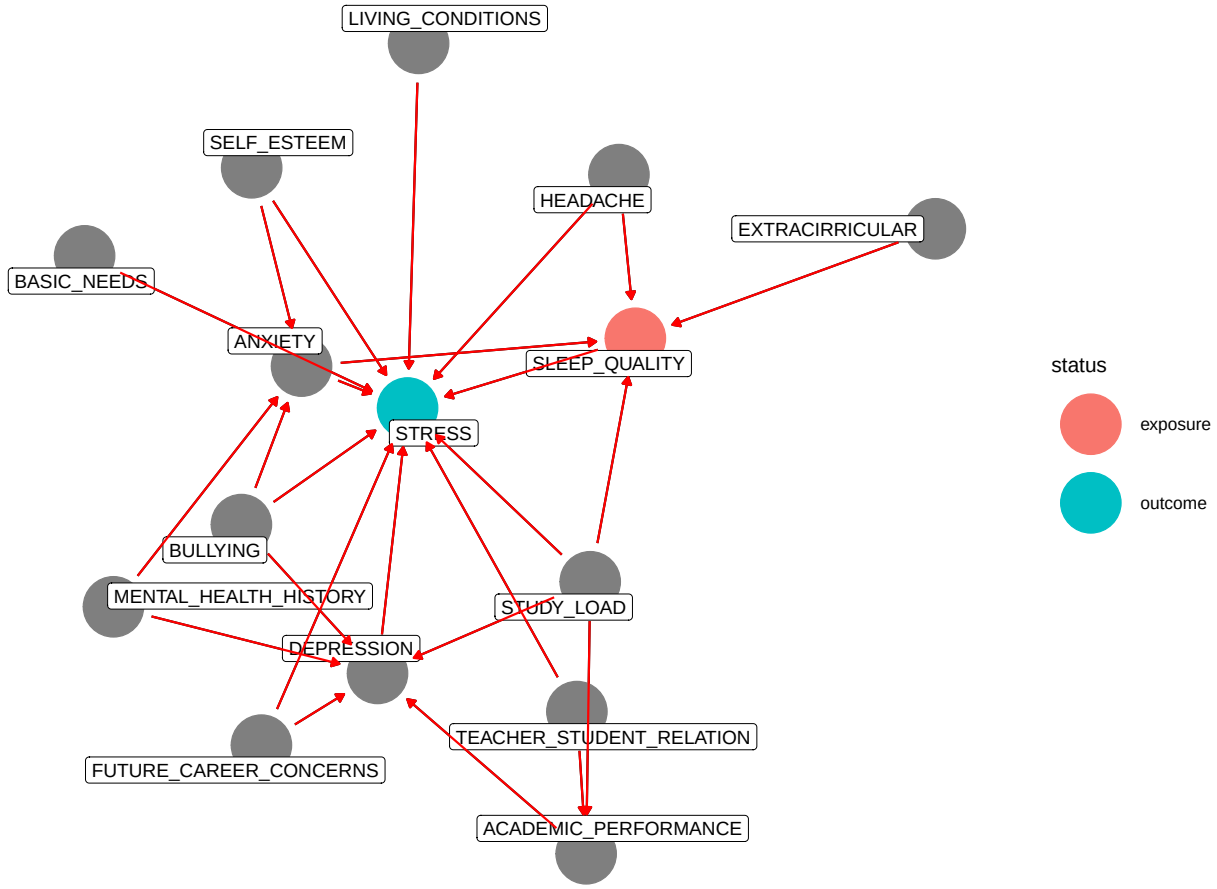
```
## Warning: package 'ggplot2' was built under R version 4.2.3
```

```
dag<-dagify(
  STRESS ~ ANXIETY + SELF_ESTEEM + DEPRESSION + HEADACHE + SLEEP_QUALITY + BASIC_NEEDS +
↪   STUDY_LOAD + TEACHER_STUDENT_RELATION + FUTURE_CAREER_CONCERNS + BULLYING
↪   +LIVING_CONDITIONS,
```

```
  SLEEP_QUALITY ~ ANXIETY + HEADACHE + STUDY_LOAD + EXTRACIRRICULAR,
  ANXIETY ~ SELF_ESTEEM + MENTAL_HEALTH_HISTORY  + BULLYING,
  DEPRESSION ~ MENTAL_HEALTH_HISTORY+ACADEMIC_PERFORMANCE + STUDY_LOAD +
↪   FUTURE_CAREER_CONCERNS + BULLYING,
  ACADEMIC_PERFORMANCE ~ STUDY_LOAD+TEACHER_STUDENT_RELATION,

  exposure = "SLEEP_QUALITY",
  outcome = "STRESS",
  labels = c(STRESS="STRESS",
             ANXIETY="ANXIETY",
             SELF_ESTEEM="SELF_ESTEEM",
             MENTAL_HEALTH_HISTORY="MENTAL_HEALTH_HISTORY",
             DEPRESSION="DEPRESSION",
             HEADACHE="HEADACHE",
             SLEEP_QUALITY="SLEEP_QUALITY",
             BASIC_NEEDS="BASIC_NEEDS",
             ACADEMIC_PERFORMANCE="ACADEMIC_PERFORMANCE",
             STUDY_LOAD="STUDY_LOAD",
             TEACHER_STUDENT_RELATION="TEACHER_STUDENT_RELATION",
             FUTURE_CAREER_CONCERNS="FUTURE_CAREER_CONCERNS",
             EXTRACIRRICULAR="EXTRACIRRICULAR",
             BULLYING="BULLYING",
             LIVING_CONDITIONS="LIVING_CONDITIONS"
             )
)
```

```
ggdag_status(dag, text = FALSE) + geom_dag_label_repel(aes(label = label),
    colour = "black", show.legend = FALSE) + geom_dag_edges_arc(edge_color = "red",
    curvature = 0) + theme_dag()
```



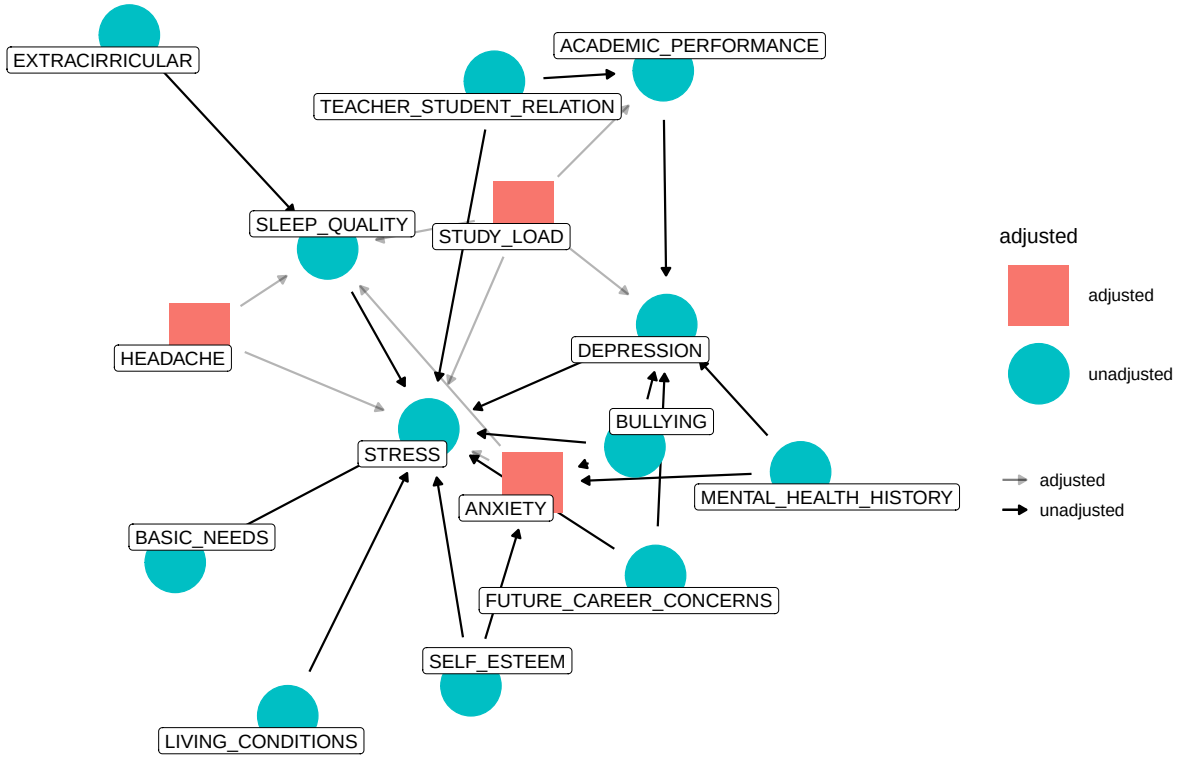
The backdoors are:(confounders)

```
adjustmentSets(dag)
```

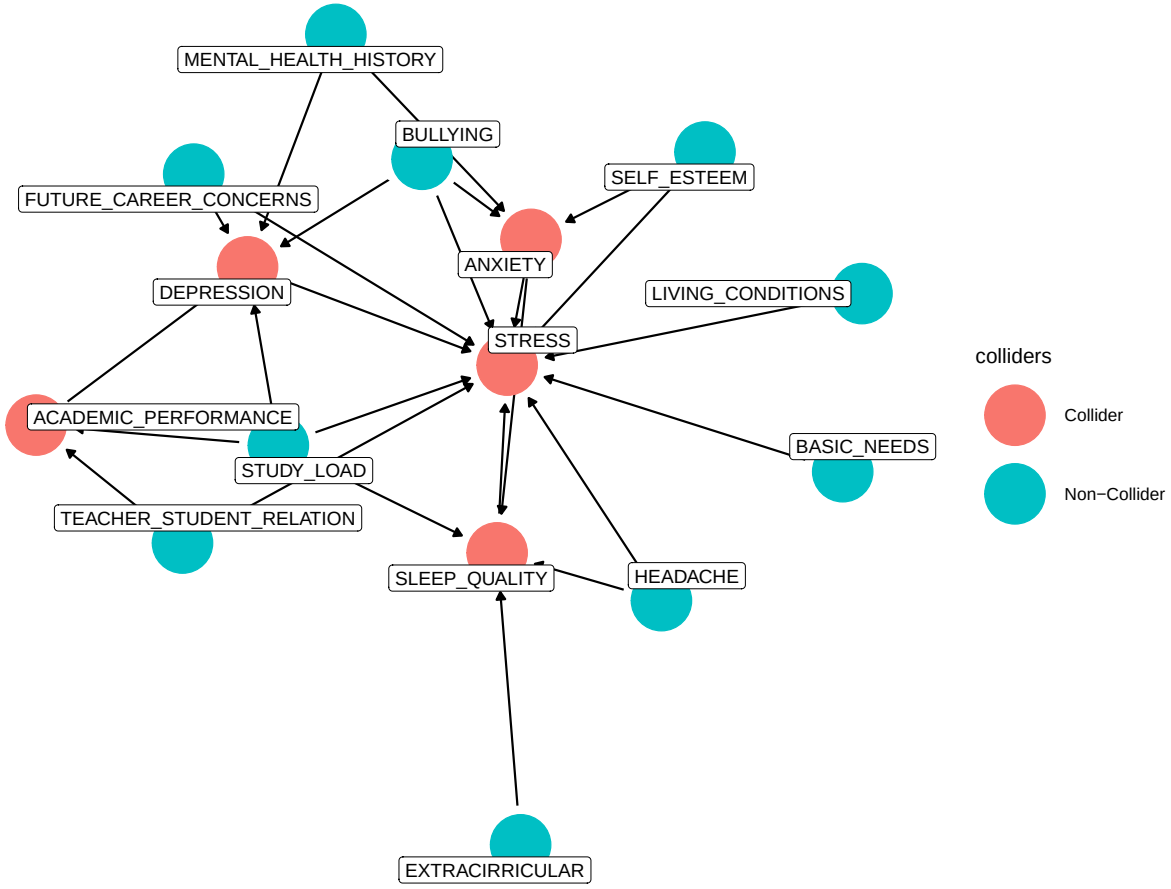
```
## { ANXIETY, HEADACHE, STUDY_LOAD }
```

```
ggdag_adjustment_set(dag, shadow = TRUE, text = FALSE) + geom_dag_label_repel(aes(label =
↪  label),
    colour = "black", show.legend = FALSE) + theme_dag()
```

{ANXIETY, HEADACHE, STUDY_LOAD}




```
ggdag_collider(dag, text = FALSE) + geom_dag_label_repel(aes(label = label),
    colour = "black", show.legend = FALSE) + theme_dag()
```



Therefore after blocking the confounders and the colliders we need to match on the following covariates: `SELF_ESTEEM`, `BASIC_NEEDS`, `FUTURE_CAREER_CONCERNS`, `BULLYING`,`LIVING CONDITIONS`

3 Checking the distribution of covariates for control and Treatment

To check for the effects of Sleep duration on stress, we need to set some thresholds on sleep duration.

```
print(mean(ssdata$sleep_quality))
```

```
## [1] 2.66
```

```
print(median(ssdata$sleep_quality))
```

```
## [1] 2.5
```

So we categorize sleep into 2 categories: - good: >2.5hrs - bad: <=2.5hrs

3.1 t-test for covariates and outcome:

The p-value estimates for the covariates in the whole data set are:

1. Self Esteem:

```
print(t.test(ssdata$self_esteem[ssdata$sleep_quality > 2.5],
    ssdata$self_esteem[ssdata$sleep_quality <= 2.5])$p.value)
```

```
## [1] 1.93977e-99
```

2. Basic Needs:

```
print(t.test(ssdata$basic_needs[ssdata$sleep_quality > 2.5],
    ssdata$basic_needs[ssdata$sleep_quality <= 2.5])$p.value)
```

```
## [1] 1.05511e-86
```

3. Future Career Concerns:

```
print(t.test(ssdata$future_career_concerns[ssdata$sleep_quality >
    2.5], ssdata$future_career_concerns[ssdata$sleep_quality <=
    2.5])$p.value)
```

```
## [1] 3.095655e-118
```

4. BUllying:

```
print(t.test(ssdata$bullying[ssdata$sleep_quality > 2.5],
↪   ssdata$bullying[ssdata$sleep_quality <=
    2.5])$p.value)
```

```
## [1] 4.708424e-119
```

5. Living Conditions

```
print(t.test(ssdata$living_conditions[ssdata$sleep_quality >
    2.5], ssdata$living_conditions[ssdata$sleep_quality <= 2.5])$p.value)
```

```
## [1] 2.884276e-57
```

3.2 Plotting the results:

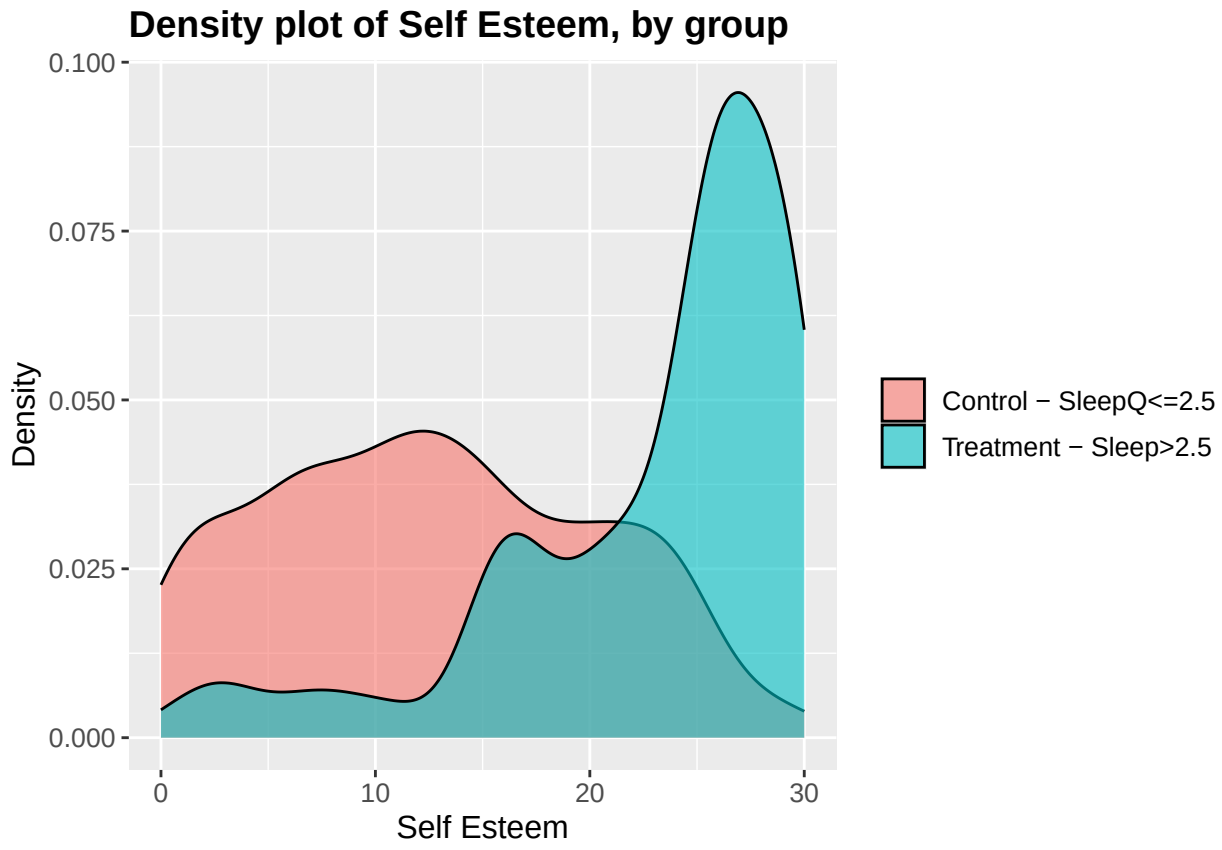
Factoring the treatment

```
ssdata$sleep_quality_treatment <- ifelse(ssdata$sleep_quality >
    2.5, 1, 0)
```

Plots:

```
ggplot(ssdata, aes(x = ssdata$self_esteem, fill =
↪   factor(ssdata$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪   "Dark2") +
    ggtitle("Density plot of Self Esteem, by group") + scale_x_continuous(name = "Self
    ↪   Esteem") +
    scale_y_continuous(name = "Density") + theme(plot.title = element_text(size = 14,
    face = "bold"), text = element_text(size = 12)) + guides(fill = guide_legend(title =
    ↪   NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

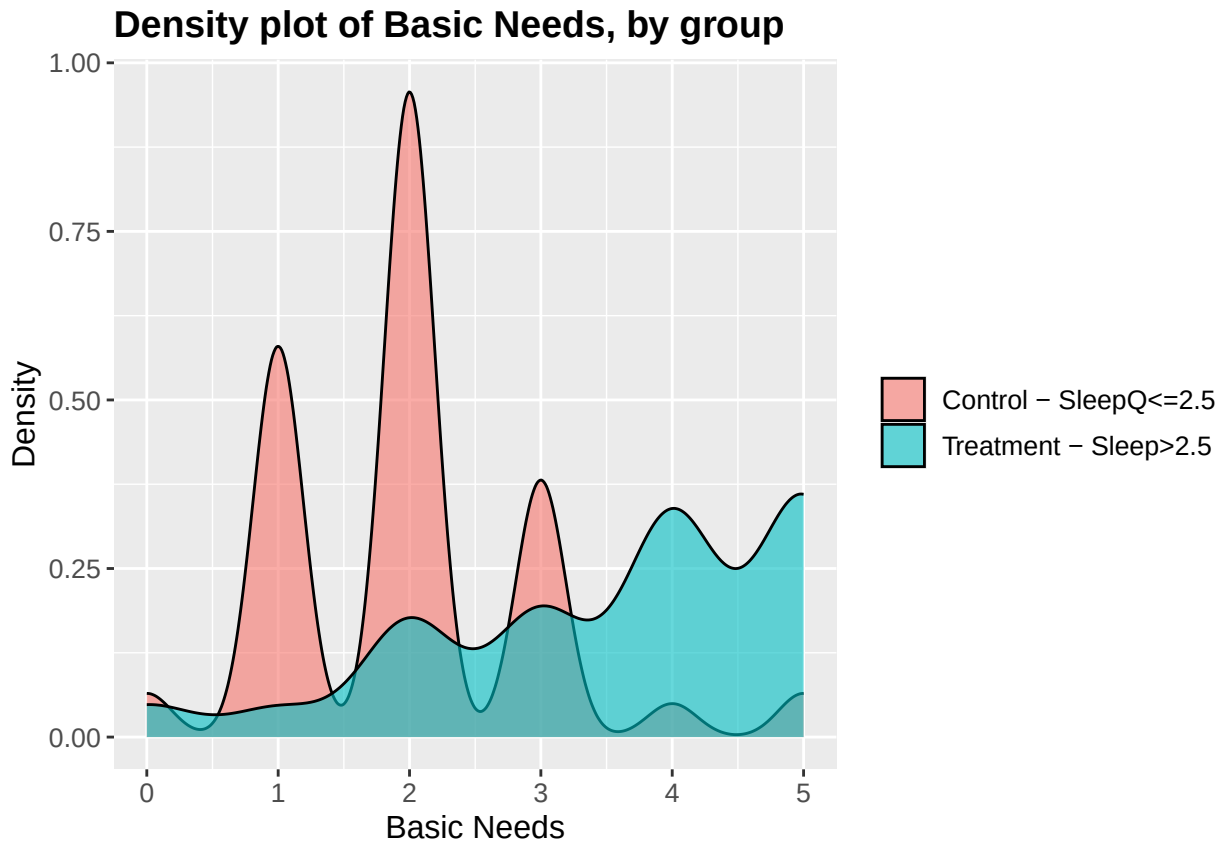
```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```




```
ggplot(ssdata, aes(x = ssdata$basic_needs, fill =
↪   factor(ssdata$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪   "Dark2") +
    ggtitle("Density plot of Basic Needs, by group") + scale_x_continuous(name = "Basic
    ↪   Needs") +
```

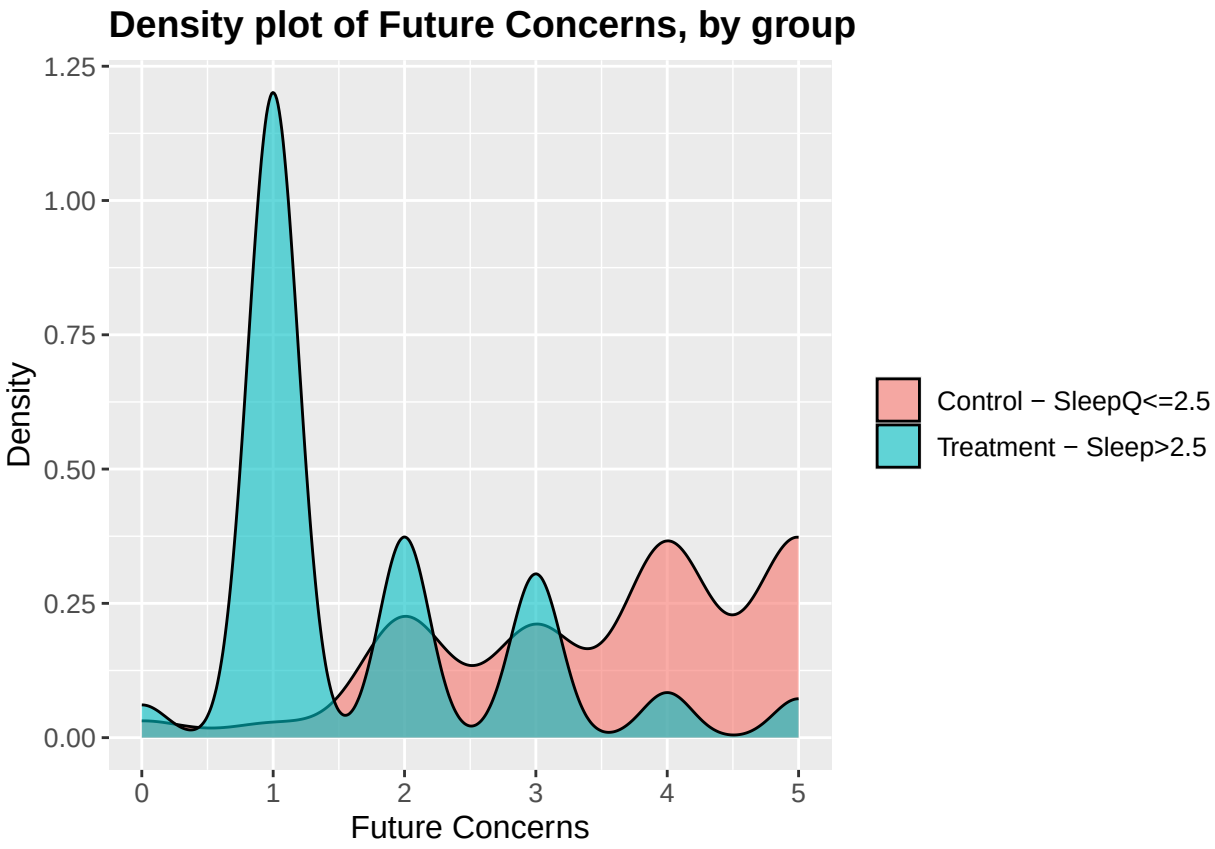
```
    scale_y_continuous(name = "Density") + theme(plot.title = element_text(size = 14,
    face = "bold"), text = element_text(size = 12)) + guides(fill = guide_legend(title =
    ↪  NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```



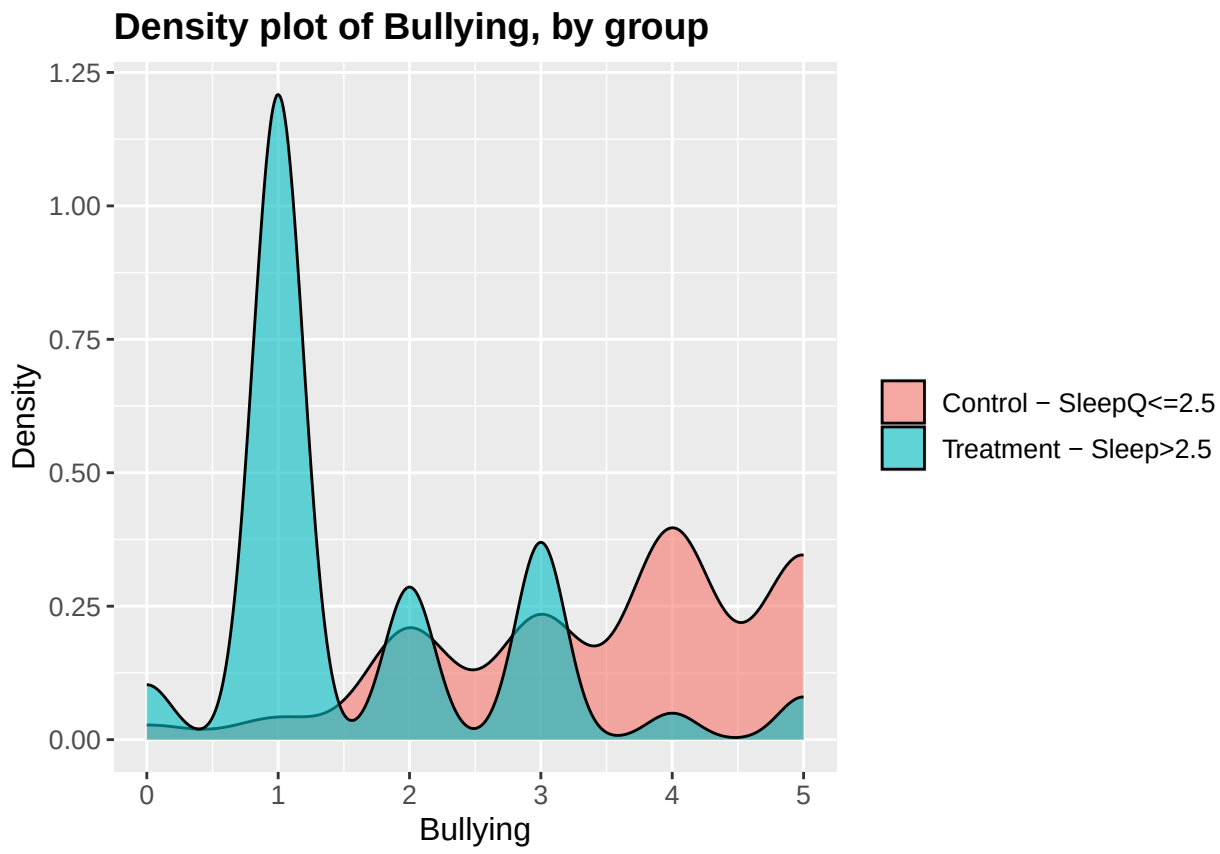

```
ggplot(ssdata, aes(x = ssdata$future_career_concerns, fill =
↪   factor(ssdata$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪  "Dark2") +
    ggtitle("Density plot of Future Concerns, by group") + scale_x_continuous(name =
    ↪  "Future Concerns") +
    scale_y_continuous(name = "Density") + theme(plot.title = element_text(size = 14,
    face = "bold"), text = element_text(size = 12)) + guides(fill = guide_legend(title =
    ↪  NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```



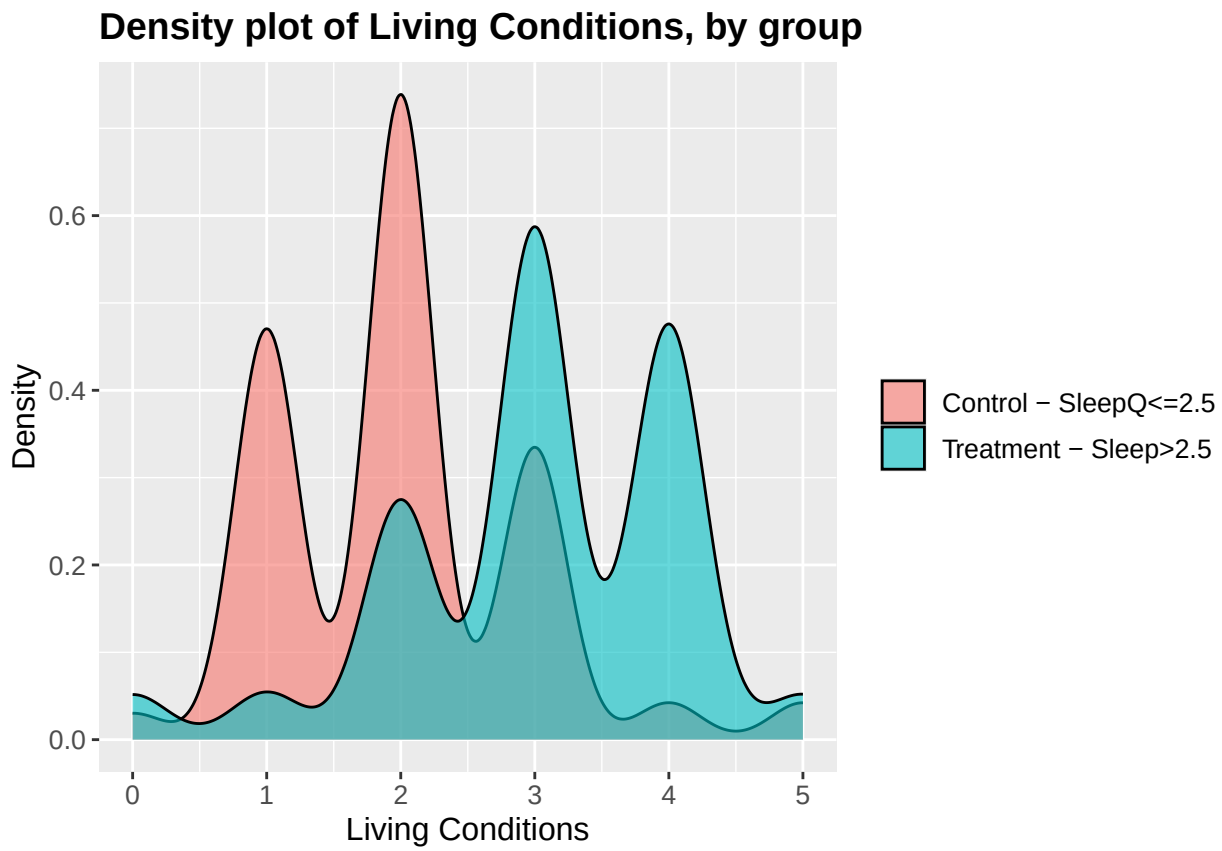

```
ggplot(ssdata, aes(x = ssdata$bullying, fill = factor(ssdata$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪  "Dark2") +
    ggtitle("Density plot of Bullying, by group") + scale_x_continuous(name = "Bullying")
    ↪  +
    scale_y_continuous(name = "Density") + theme(plot.title = element_text(size = 14,
    face = "bold"), text = element_text(size = 12)) + guides(fill = guide_legend(title =
    ↪  NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```




```
ggplot(ssdata, aes(x = ssdata$living_conditions, fill =
↪   factor(ssdata$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪   "Dark2") +
    ggtitle("Density plot of Living Conditions, by group") +
    scale_x_continuous(name = "Living Conditions") + scale_y_continuous(name = "Density")
    ↪   +
    theme(plot.title = element_text(size = 14, face = "bold"),
        text = element_text(size = 12)) + guides(fill = guide_legend(title = NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```



Findings: We find that there is a variation in covariates which needs to be mathced in order to properly uncerstand the causal effect of treatment on the outcome.(extremely low p-values)

4 Matching

```
formula <- sleep_quality_treatment ~ self_esteem + basic_needs +
    future_career_concerns + bullying + living_conditions
```

```
regmodel <- glm(sleep_quality_treatment ~ self_esteem + basic_needs +
    future_career_concerns + bullying + living_conditions, data = ssdata,
    family = "binomial")
ssdata$propscore <- predict(regmodel, newdata = ssdata, type = "response")
head(ssdata$propscore)
```

```
##         1         2         3         4         5         6
## 0.52732347 0.03377340 0.58377955 0.07231744 0.39368141 0.03946239
```

4.1 Nearest Neighbour:(without replacement)

```r
library(MatchIt)
```

```
## Warning: package 'MatchIt' was built under R version 4.2.3
```

```r
m_without_replacement = matchit(sleep_quality_treatment ~ self_esteem +
    basic_needs + future_career_concerns + bullying + living_conditions,
    method = "nearest", data = ssdata)
m_without_replacement_df <- match.data(m_without_replacement)
summary(m_without_replacement)
```

```
##
## Call:
## matchit(formula = sleep_quality_treatment ~ self_esteem + basic_needs +
##     future_career_concerns + bullying + living_conditions, data = ssdata,
##     method = "nearest")
##
## Summary of Balance for All Data:
##                         Means Treated Means Control Std. Mean Diff. Var. Ratio
## distance                       0.7351        0.2649          1.8290     0.9994
## self_esteem                   22.9564       12.5982          1.4893     0.8334
## basic_needs                    3.5618        1.9836          1.1415     1.9994
## future_career_concerns         1.6982        3.6000         -1.7242     0.7356
## bullying                       1.6636        3.5709         -1.6881     0.8011
## living_conditions              3.0273        2.0091          0.9719     1.2324
##                         eCDF Mean eCDF Max
## distance                   0.4237   0.5673
## self_esteem                0.3341   0.5436
## basic_needs                0.2667   0.5491
## future_career_concerns     0.3170   0.5545
## bullying                   0.3179   0.5709
## living_conditions          0.1752   0.4927
##
## Summary of Balance for Matched Data:
##                         Means Treated Means Control Std. Mean Diff. Var. Ratio
## distance                       0.7351        0.2649          1.8290     0.9994
## self_esteem                   22.9564       12.5982          1.4893     0.8334
## basic_needs                    3.5618        1.9836          1.1415     1.9994
## future_career_concerns         1.6982        3.6000         -1.7242     0.7356
## bullying                       1.6636        3.5709         -1.6881     0.8011
## living_conditions              3.0273        2.0091          0.9719     1.2324
##                         eCDF Mean eCDF Max Std. Pair Dist.
## distance                   0.4237   0.5673          1.8290
## self_esteem                0.3341   0.5436          1.5479
## basic_needs                0.2667   0.5491          1.2677
## future_career_concerns     0.3170   0.5545          1.7737
## bullying                   0.3179   0.5709          1.7203
## living_conditions          0.1752   0.4927          1.2009
##
## Sample Sizes:
##           Control Treated
## All           550     550
```

```
## Matched       550     550
## Unmatched       0       0
## Discarded       0       0
```

4.2 Nearest Neighbour: (With replacement)

```
m_with_replacement = matchit(sleep_quality_treatment ~ self_esteem +
    basic_needs + future_career_concerns + bullying + living_conditions,
    method = "nearest", data = ssdata, replace = TRUE)
m_with_replacement_df <- match.data(m_with_replacement)
summary(m_with_replacement)
```

```
##
## Call:
## matchit(formula = sleep_quality_treatment ~ self_esteem + basic_needs +
##     future_career_concerns + bullying + living_conditions, data = ssdata,
##     method = "nearest", replace = TRUE)
##
## Summary of Balance for All Data:
##                         Means Treated Means Control Std. Mean Diff. Var. Ratio
## distance                       0.7351        0.2649          1.8290     0.9994
## self_esteem                   22.9564       12.5982          1.4893     0.8334
## basic_needs                    3.5618        1.9836          1.1415     1.9994
## future_career_concerns         1.6982        3.6000         -1.7242     0.7356
## bullying                       1.6636        3.5709         -1.6881     0.8011
## living_conditions              3.0273        2.0091          0.9719     1.2324
##                         eCDF Mean eCDF Max
## distance                   0.4237   0.5673
## self_esteem                0.3341   0.5436
## basic_needs                0.2667   0.5491
## future_career_concerns     0.3170   0.5545
## bullying                   0.3179   0.5709
## living_conditions          0.1752   0.4927
##
## Summary of Balance for Matched Data:
##                         Means Treated Means Control Std. Mean Diff. Var. Ratio
## distance                       0.7351        0.7351          0.0001     0.8581
## self_esteem                   22.9564       22.5327          0.0609     0.8313
## basic_needs                    3.5618        3.1491          0.2985     0.8399
## future_career_concerns         1.6982        1.3673          0.3000     0.5956
## bullying                       1.6636        1.7491         -0.0756     0.6667
## living_conditions              3.0273        3.2109         -0.1753     0.6213
##                         eCDF Mean eCDF Max Std. Pair Dist.
## distance                   0.0058   0.2382          0.0173
## self_esteem                0.0342   0.1745          0.5613
## basic_needs                0.0906   0.2527          0.9561
## future_career_concerns     0.0600   0.3164          0.5868
## bullying                   0.0997   0.3200          0.7451
## living_conditions          0.0476   0.2073          0.8764
##
## Sample Sizes:
```

```
##               Control Treated
## All            550.       550
## Matched (ESS)    7.04     550
## Matched        137.       550
## Unmatched      413.         0
## Discarded        0.         0
```

4.3 Nearest Neighbour method: (With replacement and caliper)

```
m_caliper = matchit(sleep_quality_treatment ~ self_esteem + basic_needs +
    future_career_concerns + bullying + living_conditions, method = "nearest",
    data = ssdata, replace = TRUE, caliper = 0.03)
m_caliper_df <- match.data(m_with_replacement)
summary(m_caliper)
```

```
##
## Call:
## matchit(formula = sleep_quality_treatment ~ self_esteem + basic_needs +
##     future_career_concerns + bullying + living_conditions, data = ssdata,
##     method = "nearest", replace = TRUE, caliper = 0.03)
##
## Summary of Balance for All Data:
##                         Means Treated Means Control Std. Mean Diff. Var. Ratio
## distance                       0.7351        0.2649          1.8290     0.9994
## self_esteem                   22.9564       12.5982          1.4893     0.8334
## basic_needs                    3.5618        1.9836          1.1415     1.9994
## future_career_concerns         1.6982        3.6000         -1.7242     0.7356
## bullying                       1.6636        3.5709         -1.6881     0.8011
## living_conditions              3.0273        2.0091          0.9719     1.2324
##                         eCDF Mean eCDF Max
## distance                   0.4237   0.5673
## self_esteem                0.3341   0.5436
## basic_needs                0.2667   0.5491
## future_career_concerns     0.3170   0.5545
## bullying                   0.3179   0.5709
## living_conditions          0.1752   0.4927
##
## Summary of Balance for Matched Data:
##                         Means Treated Means Control Std. Mean Diff. Var. Ratio
## distance                       0.6999        0.6995          0.0013     0.8889
## self_esteem                   22.2586       22.1789          0.0115     0.9693
## basic_needs                    3.4461        3.0237          0.3055     1.0123
## future_career_concerns         1.8211        1.5711          0.2267     0.6539
## bullying                       1.7909        1.8556         -0.0572     0.7276
## living_conditions              2.9030        3.1250         -0.2119     0.6321
##                         eCDF Mean eCDF Max Std. Pair Dist.
## distance                   0.0039   0.2069          0.0103
## self_esteem                0.0226   0.1638          0.5345
## basic_needs                0.0955   0.2263          0.9259
## future_career_concerns     0.0510   0.2457          0.5588
## bullying                   0.0898   0.2737          0.7211
```

```
## living_conditions         0.0420   0.2047          0.8907
##
## Sample Sizes:
##                Control Treated
## All             550.       550
## Matched (ESS)     8.82     464
## Matched         137.       464
## Unmatched       413.        86
## Discarded         0.         0
```

5 Post Match Plotting:

5.1 without replacement:

5.1.1 t-tests:

1. Self Esteem:

```
print(t.test(m_without_replacement_df$self_esteem[m_without_replacement_df$sleep_quality
↪  >
   2.5], m_without_replacement_df$self_esteem[m_without_replacement_df$sleep_quality <=
   2.5])$p.value)
```

```
## [1] 1.93977e-99
```

2. Basic Needs:

```
print(t.test(m_without_replacement_df$basic_needs[m_without_replacement_df$sleep_quality
↪  >
   2.5], m_without_replacement_df$basic_needs[m_without_replacement_df$sleep_quality <=
   2.5])$p.value)
```

```
## [1] 1.05511e-86
```

3. Future Career Concerns:

```
print(t.test(m_without_replacement_df$future_career_concerns[m_without_replacement_df$sleep_quality
↪  >
   2.5],
    ↪  m_without_replacement_df$future_career_concerns[m_without_replacement_df$sleep_quality
    ↪  <=
   2.5])$p.value)
```

```
## [1] 3.095655e-118
```

4. BUllying:

```
print(t.test(m_without_replacement_df$bullying[m_without_replacement_df$sleep_quality >
    2.5], m_without_replacement_df$bullying[m_without_replacement_df$sleep_quality <=
    2.5])$p.value)
```

```
## [1] 4.708424e-119
```

5. Living Conditions

```
print(t.test(m_without_replacement_df$living_conditions[m_without_replacement_df$sleep_quality
↪  >
    2.5],
    ↪  m_without_replacement_df$living_conditions[m_without_replacement_df$sleep_quality
    ↪  <=
    2.5])$p.value)
```

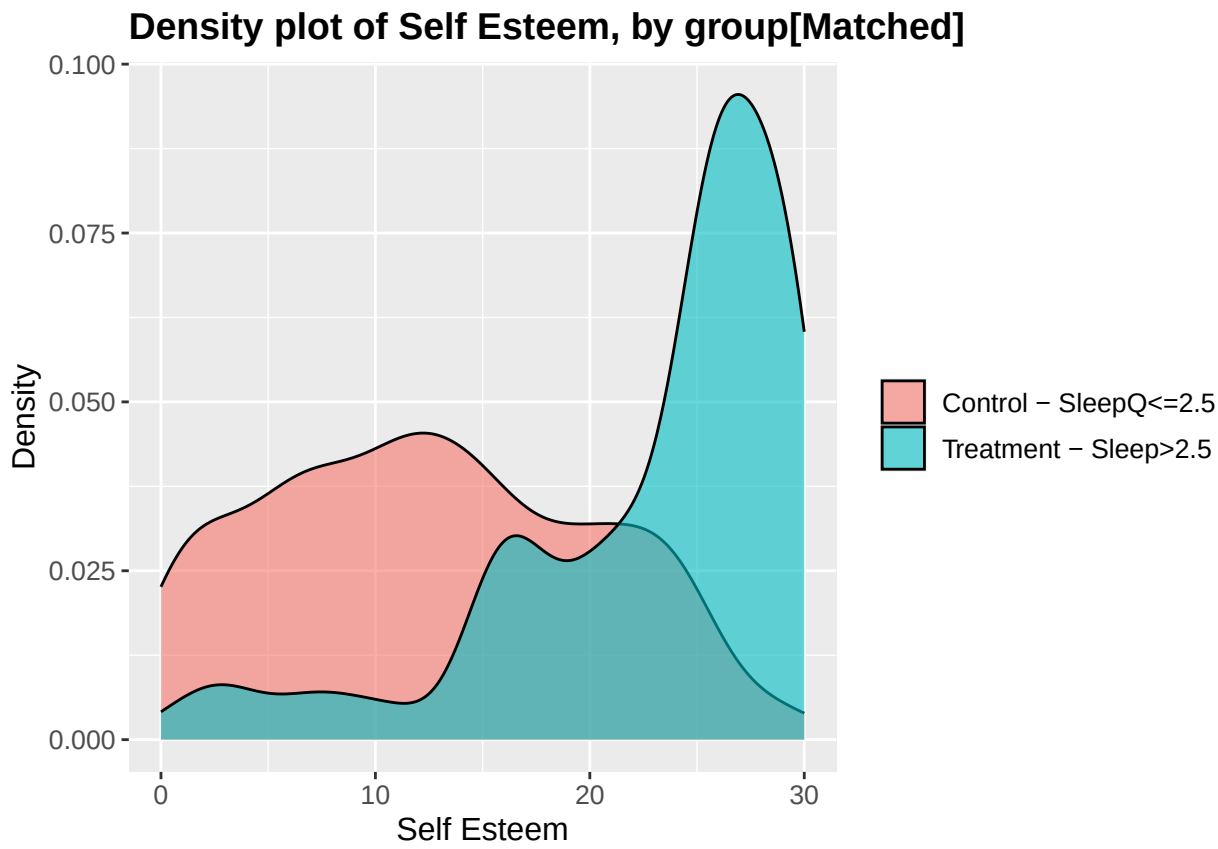
```
## [1] 2.884276e-57
```

```
ggplot(m_without_replacement_df, aes(x = m_without_replacement_df$self_esteem,
    fill = factor(m_without_replacement_df$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪  "Dark2") +
    ggtitle("Density plot of Self Esteem, by group[Matched]") +
    scale_x_continuous(name = "Self Esteem") + scale_y_continuous(name = "Density") +
    theme(plot.title = element_text(size = 14, face = "bold"),
        text = element_text(size = 12)) + guides(fill = guide_legend(title = NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
## Warning: Use of `m_without_replacement_df$self_esteem` is discouraged.
## i Use `self_esteem` instead.
```

```
## Warning: Use of `m_without_replacement_df$sleep_quality_treatment` is discouraged.
## i Use `sleep_quality_treatment` instead.
```

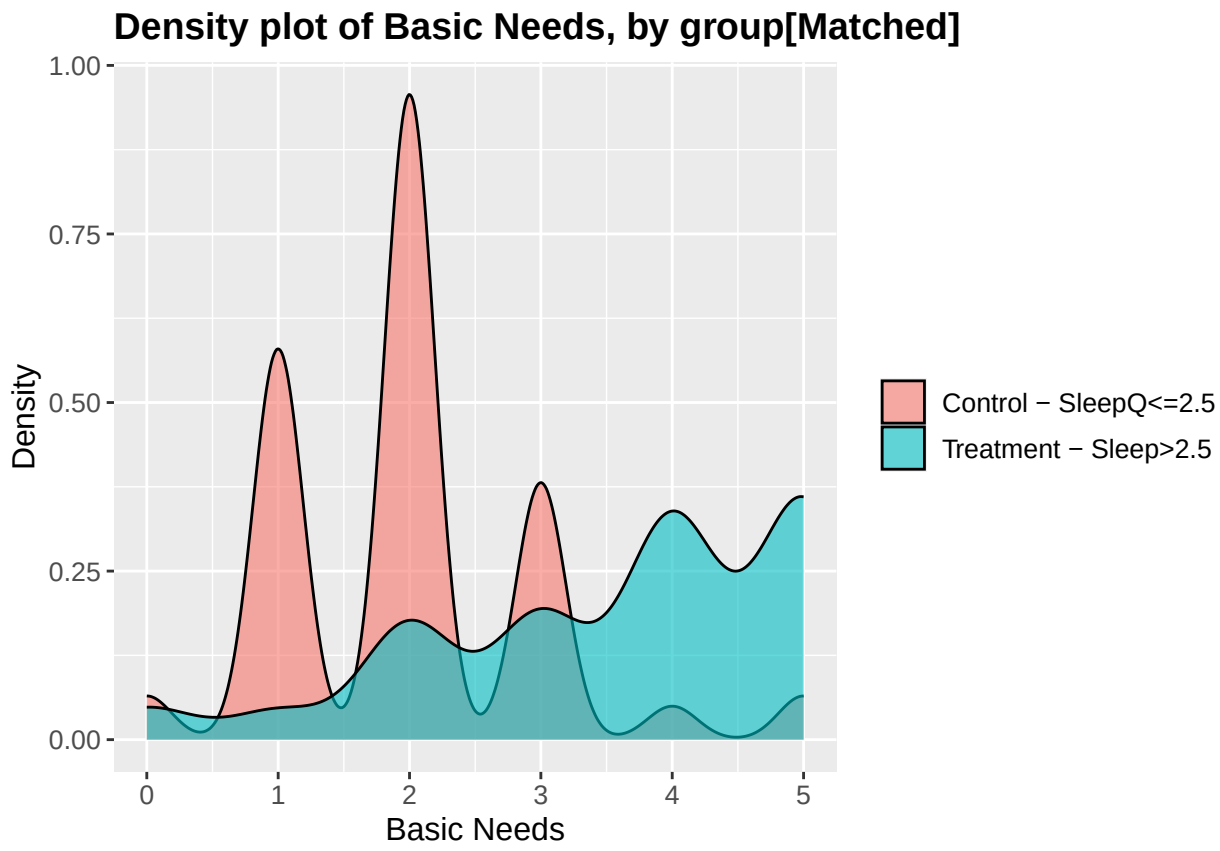



```
ggplot(m_without_replacement_df, aes(x = m_without_replacement_df$basic_needs,
    fill = factor(m_without_replacement_df$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪  "Dark2") +
    ggtitle("Density plot of Basic Needs, by group[Matched]") +
    scale_x_continuous(name = "Basic Needs") + scale_y_continuous(name = "Density") +
    theme(plot.title = element_text(size = 14, face = "bold"),
        text = element_text(size = 12)) + guides(fill = guide_legend(title = NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
## Warning: Use of `m_without_replacement_df$basic_needs` is discouraged.
## i Use `basic_needs` instead.
```

```
## Warning: Use of `m_without_replacement_df$sleep_quality_treatment` is discouraged.
## i Use `sleep_quality_treatment` instead.
```

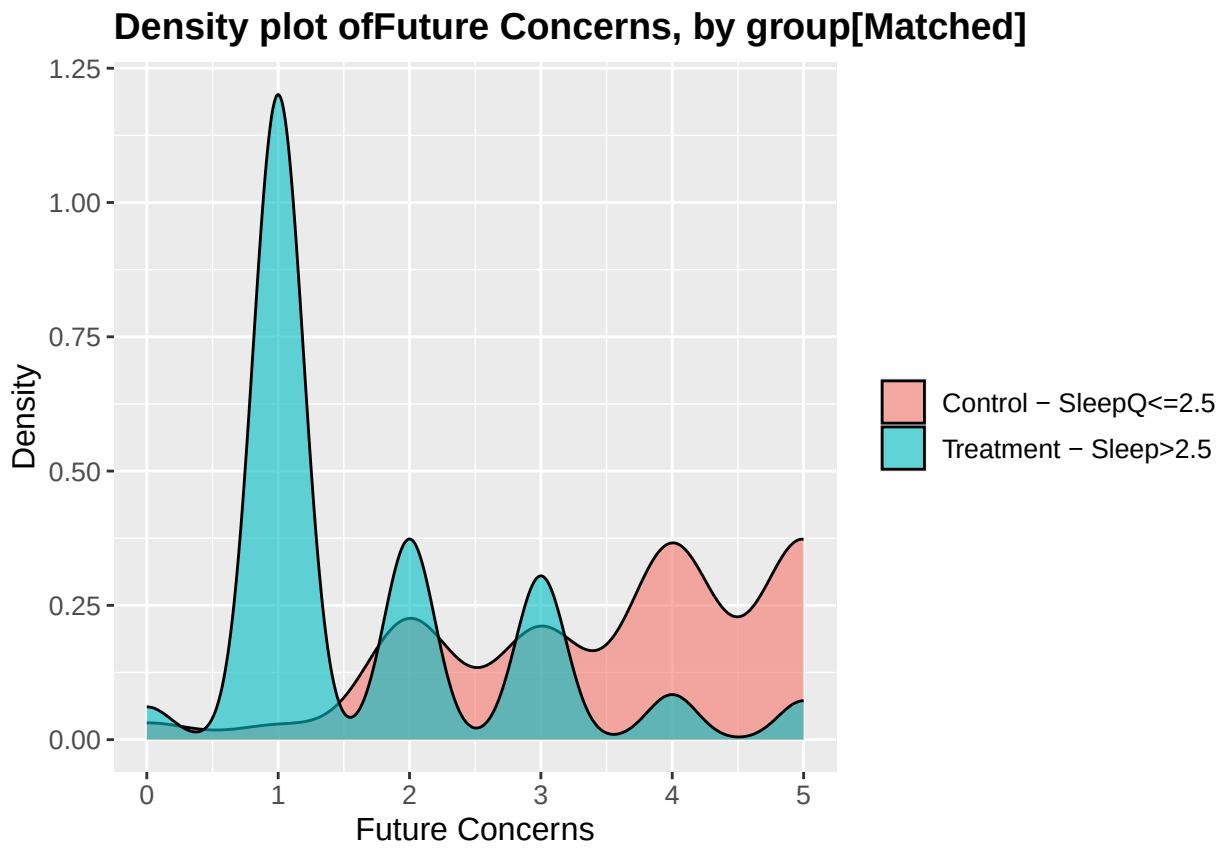



```
ggplot(m_without_replacement_df, aes(x = m_without_replacement_df$future_career_concerns,
    fill = factor(m_without_replacement_df$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪  "Dark2") +
    ggtitle("Density plot ofFuture Concerns, by group[Matched]") +
    scale_x_continuous(name = "Future Concerns") + scale_y_continuous(name = "Density") +
    theme(plot.title = element_text(size = 14, face = "bold"),
        text = element_text(size = 12)) + guides(fill = guide_legend(title = NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
## Warning: Use of `m_without_replacement_df$future_career_concerns` is discouraged.
## i Use `future_career_concerns` instead.
```

```
## Warning: Use of `m_without_replacement_df$sleep_quality_treatment` is discouraged.
## i Use `sleep_quality_treatment` instead.
```

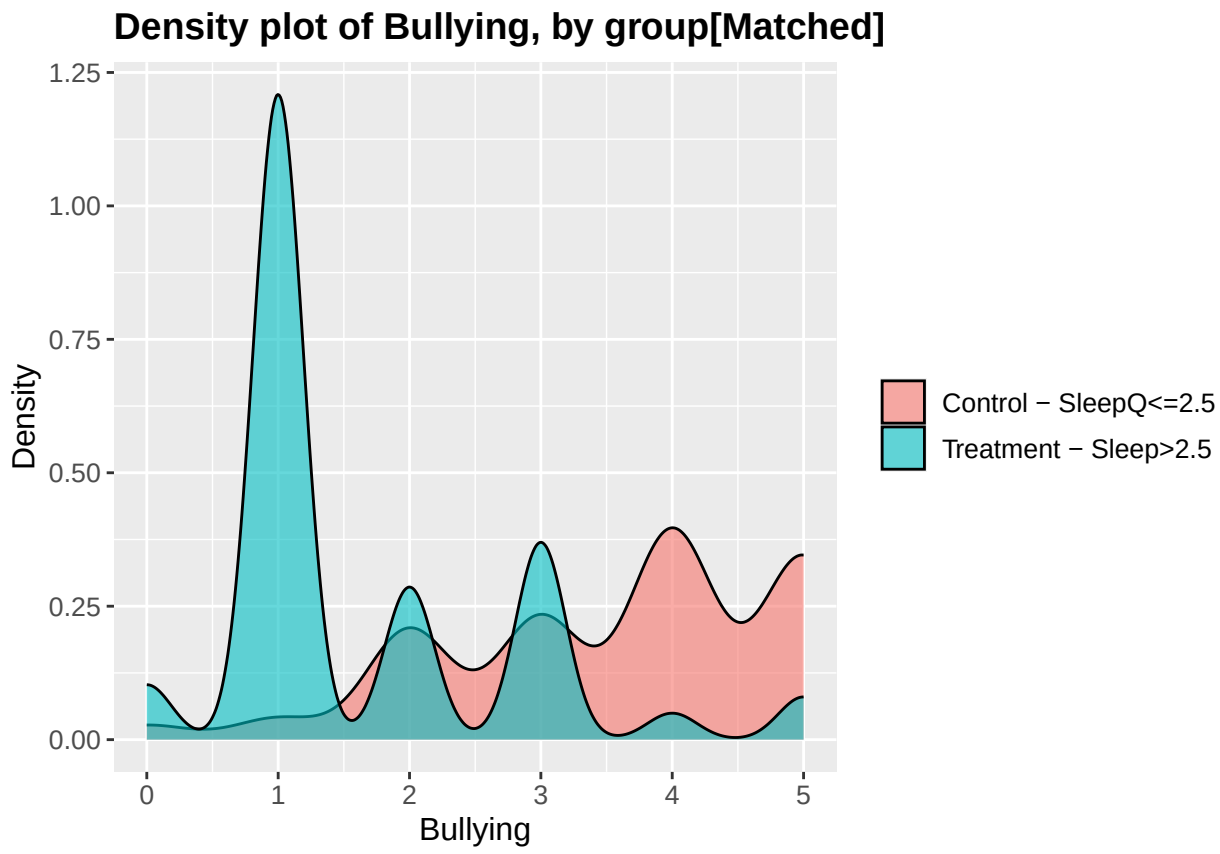



```
ggplot(m_without_replacement_df, aes(x = m_without_replacement_df$bullying,
    fill = factor(m_without_replacement_df$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪  "Dark2") +
    ggtitle("Density plot of Bullying, by group[Matched]") +
    scale_x_continuous(name = "Bullying") + scale_y_continuous(name = "Density") +
    theme(plot.title = element_text(size = 14, face = "bold"),
        text = element_text(size = 12)) + guides(fill = guide_legend(title = NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
## Warning: Use of `m_without_replacement_df$bullying` is discouraged.
## i Use `bullying` instead.
```

```
## Warning: Use of `m_without_replacement_df$sleep_quality_treatment` is discouraged.
## i Use `sleep_quality_treatment` instead.
```

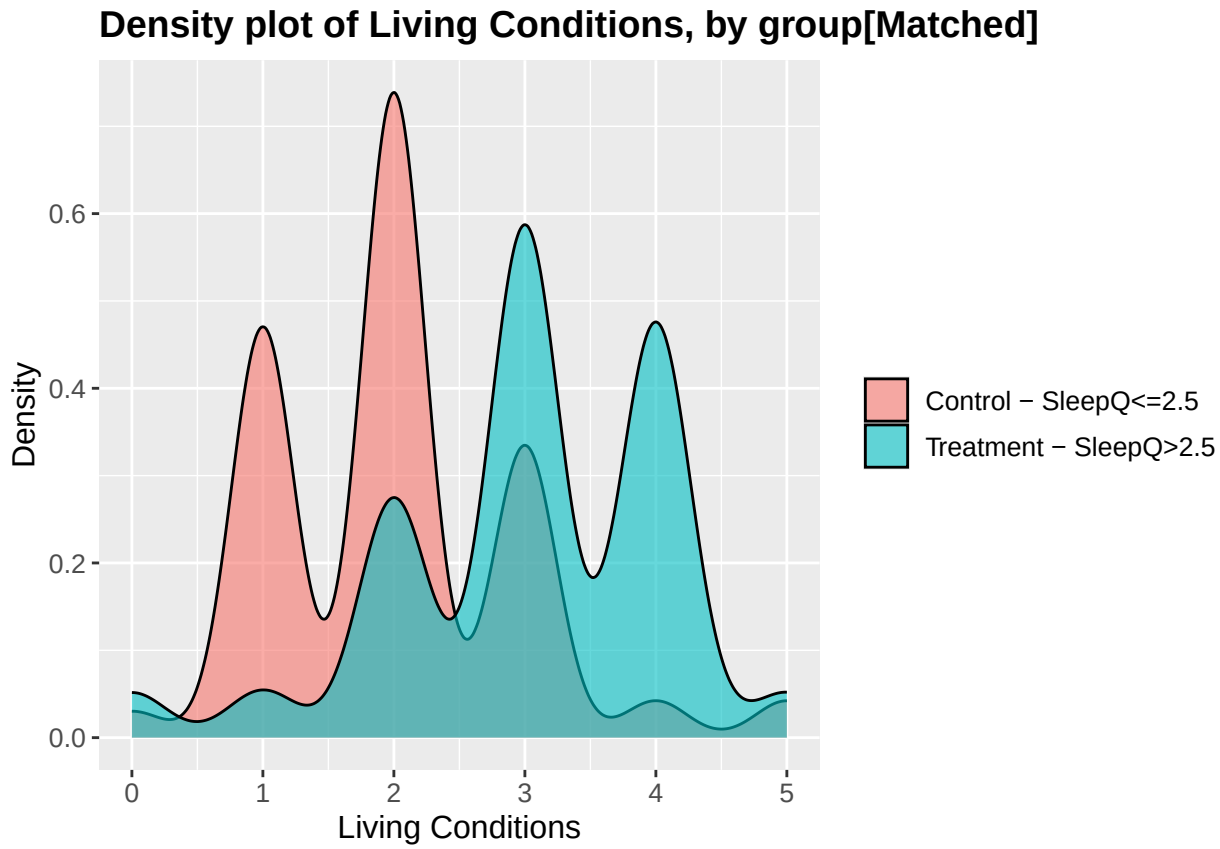



```
ggplot(m_without_replacement_df, aes(x = m_without_replacement_df$living_conditions,
    fill = factor(m_without_replacement_df$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪  "Dark2") +
    ggtitle("Density plot of Living Conditions, by group[Matched]") +
    scale_x_continuous(name = "Living Conditions") + scale_y_continuous(name = "Density")
    ↪  +
    theme(plot.title = element_text(size = 14, face = "bold"),
        text = element_text(size = 12)) + guides(fill = guide_legend(title = NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - SleepQ>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
## Warning: Use of `m_without_replacement_df$living_conditions` is discouraged.
## i Use `living_conditions` instead.
```

```
## Warning: Use of `m_without_replacement_df$sleep_quality_treatment` is discouraged.
## i Use `sleep_quality_treatment` instead.
```



5.2 with replacement

5.2.1 t-tests:

1. Self Esteem:

```
print(t.test(m_with_replacement_df$self_esteem[m_with_replacement_df$sleep_quality >
    2.5][1:137], m_with_replacement_df$self_esteem[m_with_replacement_df$sleep_quality <=
    2.5][1:137])$p.value)
```

```
## [1] 2.625316e-08
```

2. Basic Needs:

```
print(t.test(m_with_replacement_df$basic_needs[m_with_replacement_df$sleep_quality >
    2.5][1:137], m_with_replacement_df$basic_needs[m_with_replacement_df$sleep_quality <=
    2.5][1:137])$p.value)
```

```
## [1] 1.46718e-11
```

3. Future Career Concerns:

```
print(t.test(m_with_replacement_df$future_career_concerns[m_with_replacement_df$sleep_quality
↪  >
    2.5][1:137],
     ↪  m_with_replacement_df$future_career_concerns[m_with_replacement_df$sleep_quality
     ↪  <=
    2.5][1:137])$p.value)
```

```
## [1] 1.933111e-10
```

4. BUllying:

```
print(t.test(m_with_replacement_df$bullying[m_with_replacement_df$sleep_quality >
    2.5][1:137], m_with_replacement_df$bullying[m_with_replacement_df$sleep_quality <=
    2.5][1:137])$p.value)
```

```
## [1] 1.115877e-14
```

5. Living Conditions

```
print(t.test(m_with_replacement_df$living_conditions[m_with_replacement_df$sleep_quality
↪  >
    2.5][1:137],
     ↪  m_with_replacement_df$living_conditions[m_with_replacement_df$sleep_quality <=
    2.5][1:137])$p.value)
```

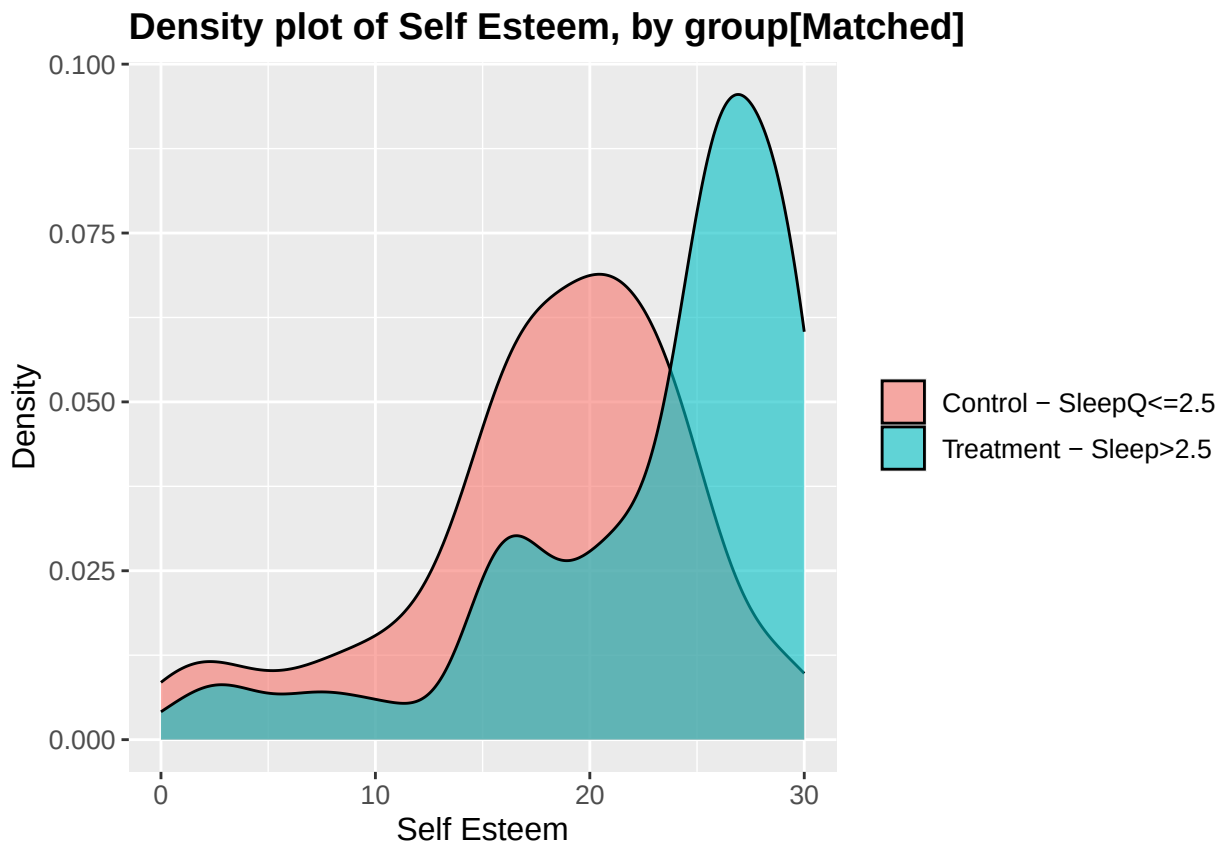
```
## [1] 1.137508e-09
```

```
ggplot(m_with_replacement_df, aes(x = m_with_replacement_df$self_esteem,
    fill = factor(m_with_replacement_df$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
     ↪  "Dark2") +
    ggtitle("Density plot of Self Esteem, by group[Matched]") +
    scale_x_continuous(name = "Self Esteem") + scale_y_continuous(name = "Density") +
    theme(plot.title = element_text(size = 14, face = "bold"),
        text = element_text(size = 12)) + guides(fill = guide_legend(title = NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
## Warning: Use of `m_with_replacement_df$self_esteem` is discouraged.
## i Use `self_esteem` instead.
```

```
## Warning: Use of `m_with_replacement_df$sleep_quality_treatment` is discouraged.
## i Use `sleep_quality_treatment` instead.
```

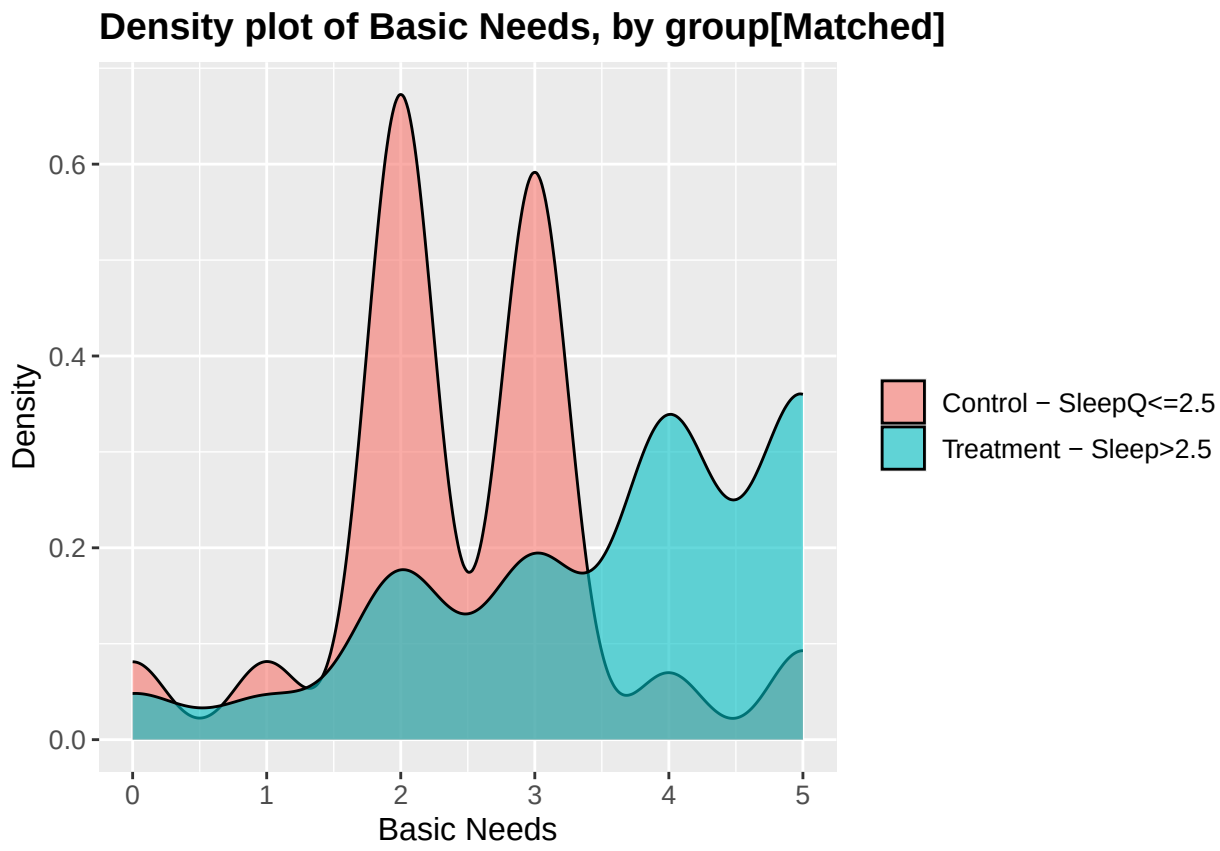



```
ggplot(m_with_replacement_df, aes(x = m_with_replacement_df$basic_needs,
    fill = factor(m_with_replacement_df$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪  "Dark2") +
    ggtitle("Density plot of Basic Needs, by group[Matched]") +
    scale_x_continuous(name = "Basic Needs") + scale_y_continuous(name = "Density") +
    theme(plot.title = element_text(size = 14, face = "bold"),
        text = element_text(size = 12)) + guides(fill = guide_legend(title = NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
## Warning: Use of `m_with_replacement_df$basic_needs` is discouraged.
## i Use `basic_needs` instead.
```

```
## Warning: Use of `m_with_replacement_df$sleep_quality_treatment` is discouraged.
## i Use `sleep_quality_treatment` instead.
```

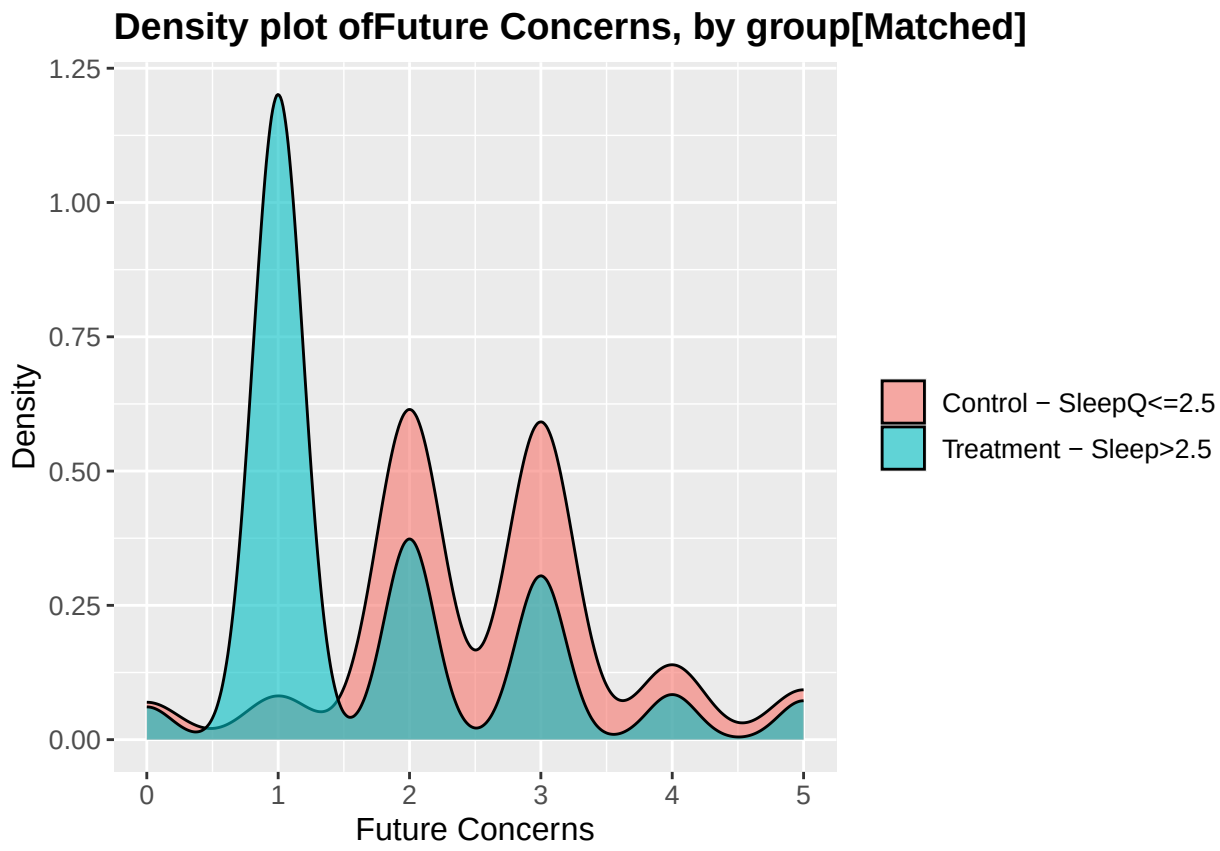



```
ggplot(m_with_replacement_df, aes(x = m_with_replacement_df$future_career_concerns,
    fill = factor(m_with_replacement_df$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪  "Dark2") +
    ggtitle("Density plot ofFuture Concerns, by group[Matched]") +
    scale_x_continuous(name = "Future Concerns") + scale_y_continuous(name = "Density") +
    theme(plot.title = element_text(size = 14, face = "bold"),
        text = element_text(size = 12)) + guides(fill = guide_legend(title = NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
## Warning: Use of `m_with_replacement_df$future_career_concerns` is discouraged.
## i Use `future_career_concerns` instead.
```

```
## Warning: Use of `m_with_replacement_df$sleep_quality_treatment` is discouraged.
## i Use `sleep_quality_treatment` instead.
```

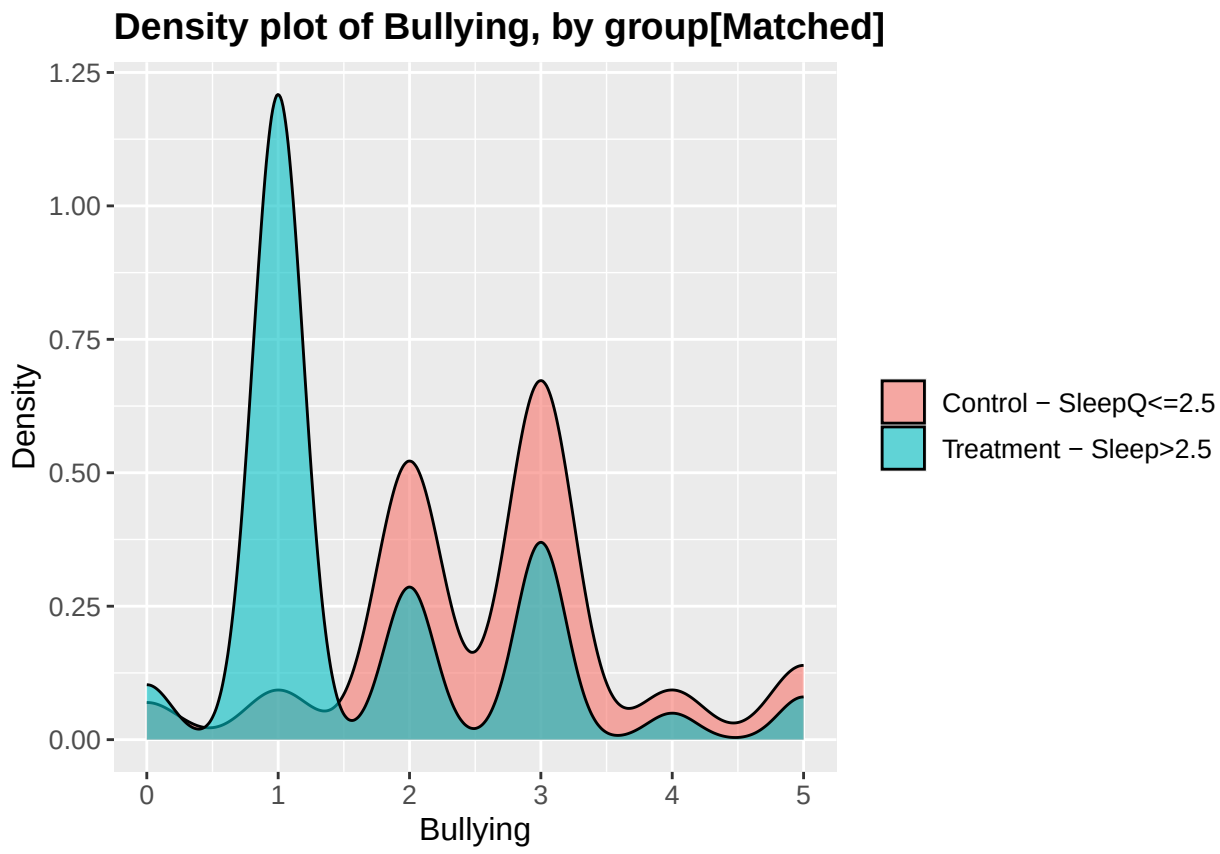



```
ggplot(m_with_replacement_df, aes(x = m_with_replacement_df$bullying,
    fill = factor(m_with_replacement_df$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪  "Dark2") +
    ggtitle("Density plot of Bullying, by group[Matched]") +
    scale_x_continuous(name = "Bullying") + scale_y_continuous(name = "Density") +
    theme(plot.title = element_text(size = 14, face = "bold"),
        text = element_text(size = 12)) + guides(fill = guide_legend(title = NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
## Warning: Use of `m_with_replacement_df$bullying` is discouraged.
## i Use `bullying` instead.
```

```
## Warning: Use of `m_with_replacement_df$sleep_quality_treatment` is discouraged.
## i Use `sleep_quality_treatment` instead.
```

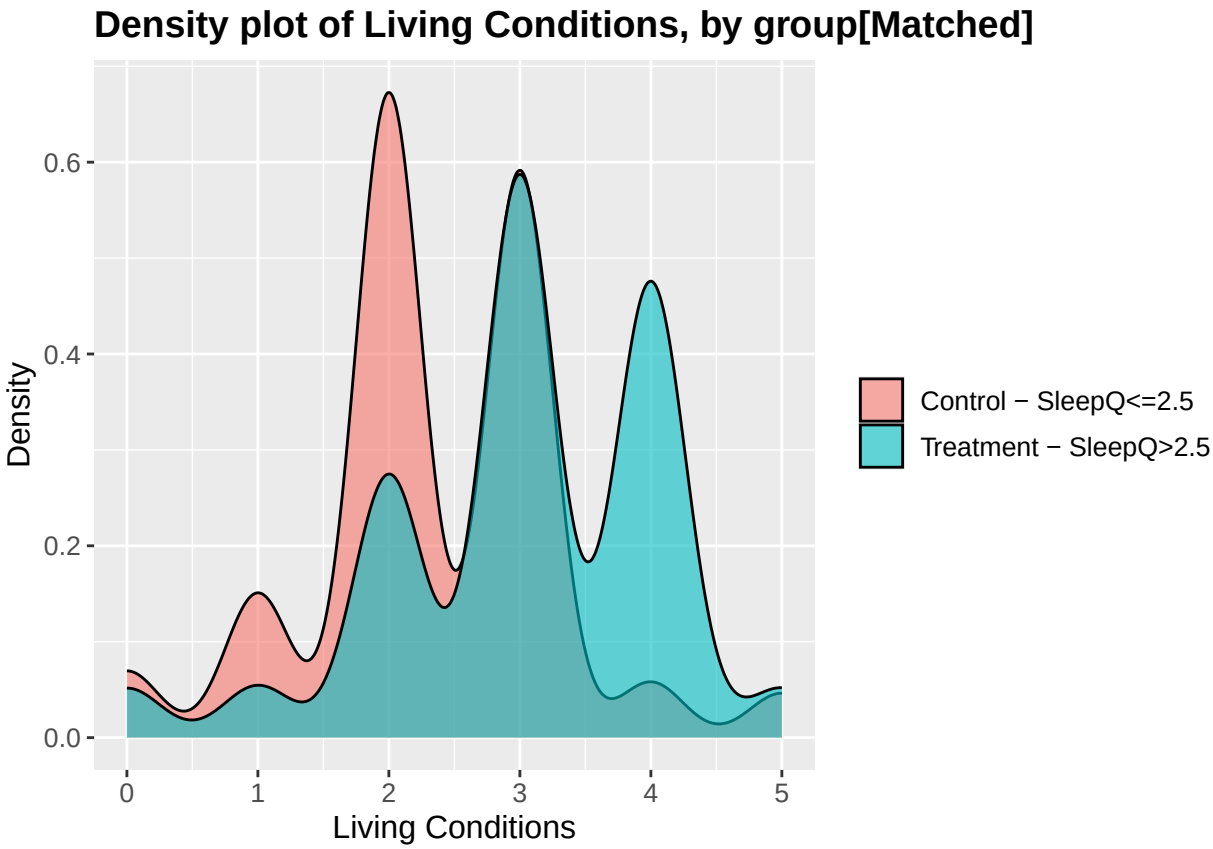



```
ggplot(m_with_replacement_df, aes(x = m_with_replacement_df$living_conditions,
    fill = factor(m_with_replacement_df$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪  "Dark2") +
    ggtitle("Density plot of Living Conditions, by group[Matched]") +
    scale_x_continuous(name = "Living Conditions") + scale_y_continuous(name = "Density")
    ↪  +
    theme(plot.title = element_text(size = 14, face = "bold"),
        text = element_text(size = 12)) + guides(fill = guide_legend(title = NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - SleepQ>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
## Warning: Use of `m_with_replacement_df$living_conditions` is discouraged.
## i Use `living_conditions` instead.
```

```
## Warning: Use of `m_with_replacement_df$sleep_quality_treatment` is discouraged.
## i Use `sleep_quality_treatment` instead.
```



5.3 with caliper

5.3.1 t-tests:

1. Self Esteem:

```
print(t.test(m_caliper_df$self_esteem[m_caliper_df$sleep_quality >
    2.5][1:137], m_caliper_df$self_esteem[m_caliper_df$sleep_quality <=
    2.5][1:137])$p.value)
```

```
## [1] 2.625316e-08
```

2. Basic Needs:

```
print(t.test(m_caliper_df$basic_needs[m_caliper_df$sleep_quality >
    2.5][1:137], m_caliper_df$basic_needs[m_caliper_df$sleep_quality <=
    2.5][1:137])$p.value)
```

```
## [1] 1.46718e-11
```

3. Future Career Concerns:

```
print(t.test(m_caliper_df$future_career_concerns[m_caliper_df$sleep_quality >
    2.5], m_caliper_df$future_career_concerns[m_caliper_df$sleep_quality <=
    2.5])$p.value)
```

```
## [1] 1.446751e-15
```

4. BUllying:

```
print(t.test(m_caliper_df$bullying[m_caliper_df$sleep_quality >
    2.5], m_caliper_df$bullying[m_caliper_df$sleep_quality <=
    2.5])$p.value)
```

```
## [1] 2.351767e-17
```

5. Living Conditions

```
print(t.test(m_caliper_df$living_conditions[m_caliper_df$sleep_quality >
    2.5], m_caliper_df$living_conditions[m_caliper_df$sleep_quality <=
    2.5])$p.value)
```

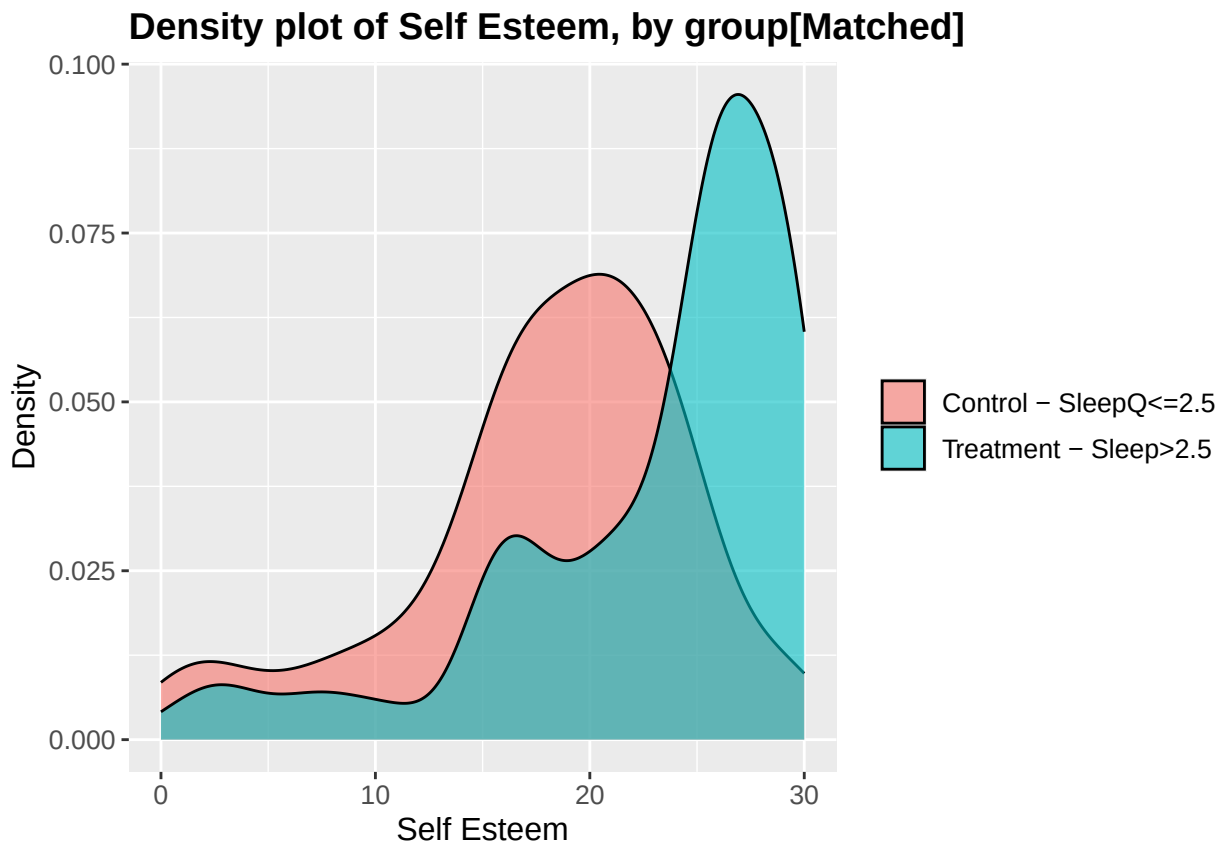
```
## [1] 8.804419e-12
```

```
ggplot(m_caliper_df, aes(x = m_caliper_df$self_esteem, fill =
↪   factor(m_caliper_df$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪   "Dark2") +
    ggtitle("Density plot of Self Esteem, by group[Matched]") +
    scale_x_continuous(name = "Self Esteem") + scale_y_continuous(name = "Density") +
    theme(plot.title = element_text(size = 14, face = "bold"),
        text = element_text(size = 12)) + guides(fill = guide_legend(title = NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
## Warning: Use of `m_caliper_df$self_esteem` is discouraged.
## i Use `self_esteem` instead.
```

```
## Warning: Use of `m_caliper_df$sleep_quality_treatment` is discouraged.
## i Use `sleep_quality_treatment` instead.
```

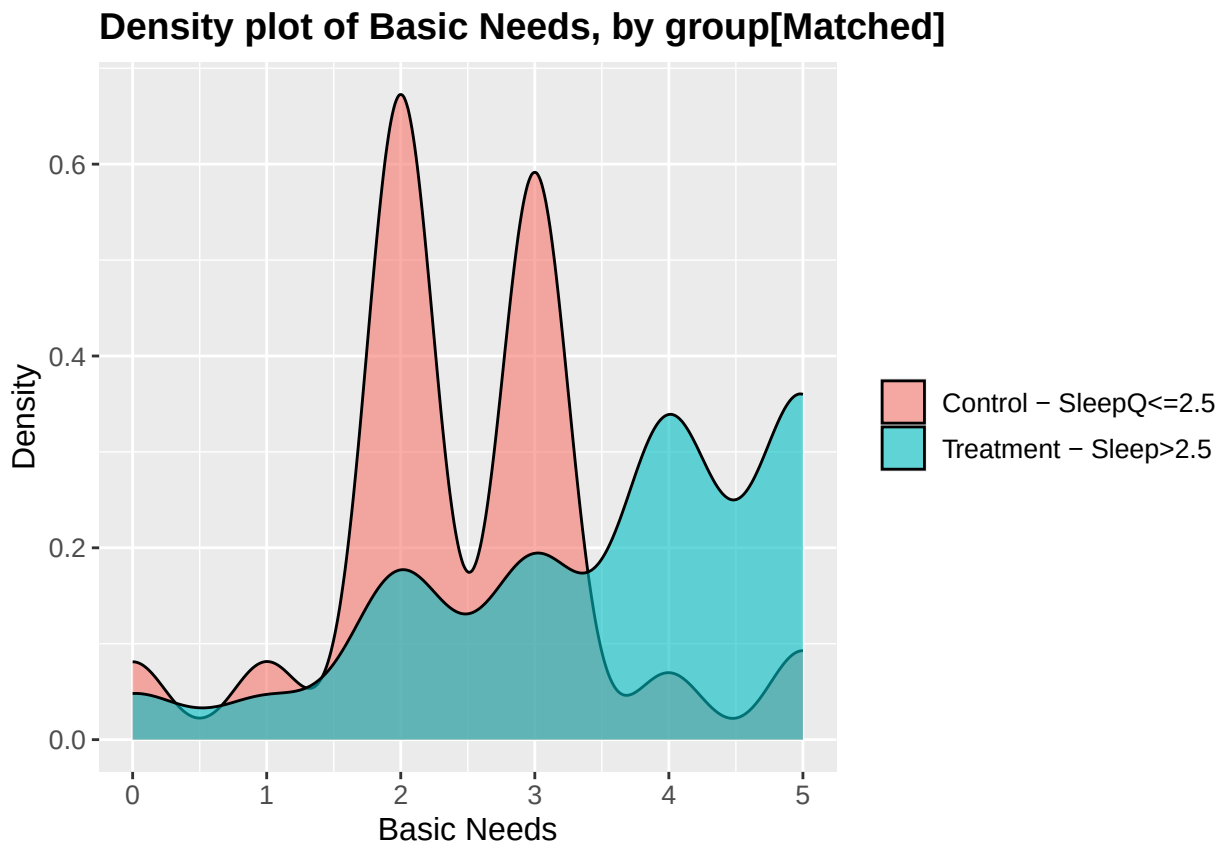



```
ggplot(m_caliper_df, aes(x = m_caliper_df$basic_needs, fill =
↪   factor(m_caliper_df$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪   "Dark2") +
    ggtitle("Density plot of Basic Needs, by group[Matched]") +
    scale_x_continuous(name = "Basic Needs") + scale_y_continuous(name = "Density") +
    theme(plot.title = element_text(size = 14, face = "bold"),
        text = element_text(size = 12)) + guides(fill = guide_legend(title = NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
## Warning: Use of `m_caliper_df$basic_needs` is discouraged.
## i Use `basic_needs` instead.
```

```
## Warning: Use of `m_caliper_df$sleep_quality_treatment` is discouraged.
## i Use `sleep_quality_treatment` instead.
```

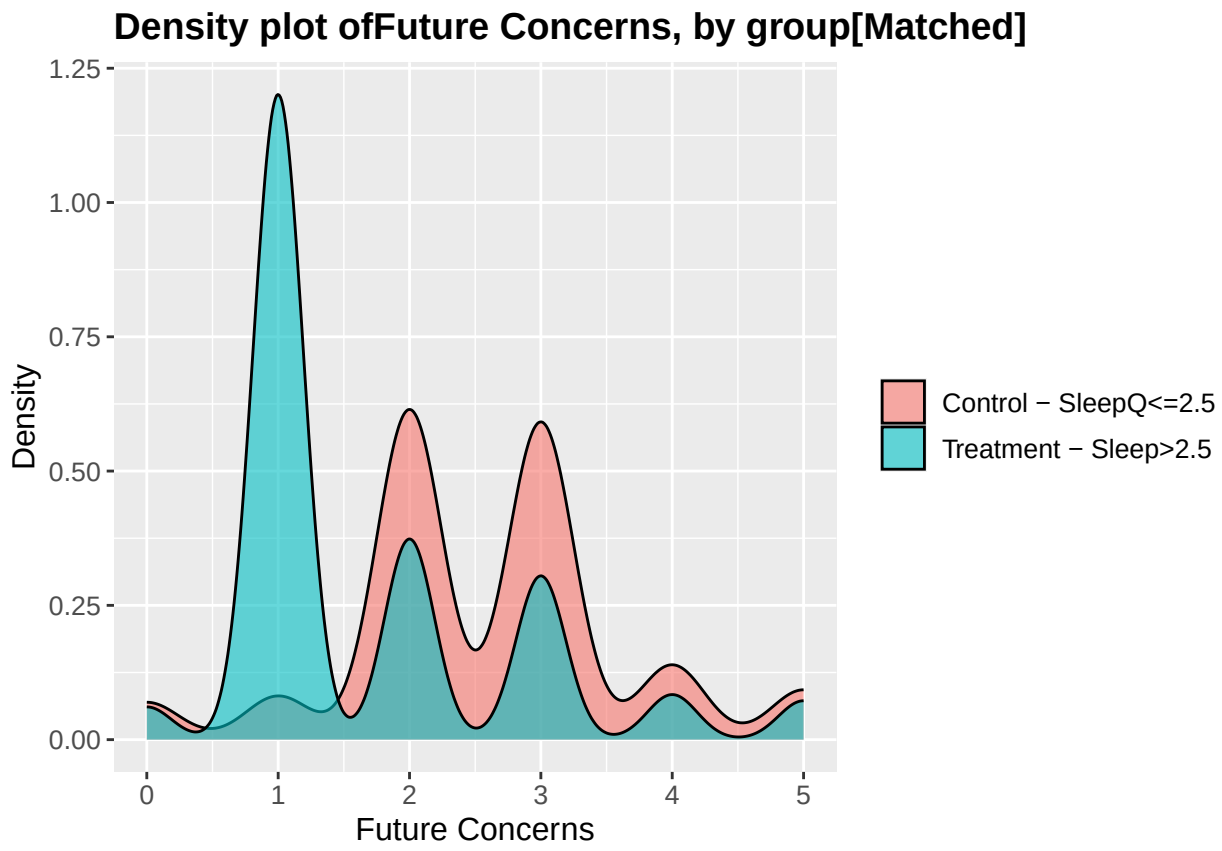



```
ggplot(m_caliper_df, aes(x = m_caliper_df$future_career_concerns,
    fill = factor(m_caliper_df$sleep_quality_treatment))) + geom_density(position =
    ↪  "identity",
    alpha = 0.6) + scale_fill_brewer(palette = "Dark2") + ggtitle("Density plot ofFuture
    ↪  Concerns, by group[Matched]") +
    scale_x_continuous(name = "Future Concerns") + scale_y_continuous(name = "Density") +
    theme(plot.title = element_text(size = 14, face = "bold"),
        text = element_text(size = 12)) + guides(fill = guide_legend(title = NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
## Warning: Use of `m_caliper_df$future_career_concerns` is discouraged.
## i Use `future_career_concerns` instead.
```

```
## Warning: Use of `m_caliper_df$sleep_quality_treatment` is discouraged.
## i Use `sleep_quality_treatment` instead.
```

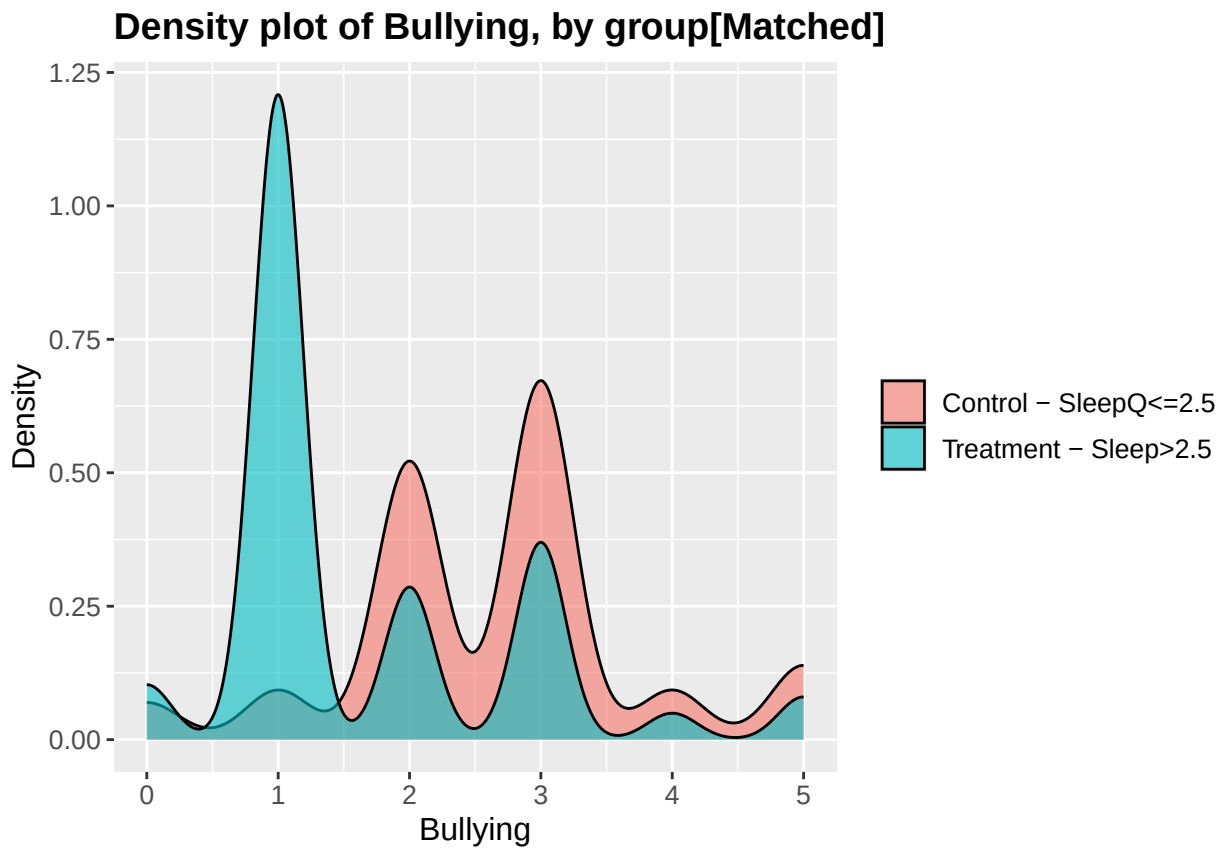



```
ggplot(m_caliper_df, aes(x = m_caliper_df$bullying, fill =
↪   factor(m_caliper_df$sleep_quality_treatment))) +
    geom_density(position = "identity", alpha = 0.6) + scale_fill_brewer(palette =
    ↪   "Dark2") +
    ggtitle("Density plot of Bullying, by group[Matched]") +
    scale_x_continuous(name = "Bullying") + scale_y_continuous(name = "Density") +
    theme(plot.title = element_text(size = 14, face = "bold"),
        text = element_text(size = 12)) + guides(fill = guide_legend(title = NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - Sleep>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
## Warning: Use of `m_caliper_df$bullying` is discouraged.
## i Use `bullying` instead.
```

```
## Warning: Use of `m_caliper_df$sleep_quality_treatment` is discouraged.
## i Use `sleep_quality_treatment` instead.
```

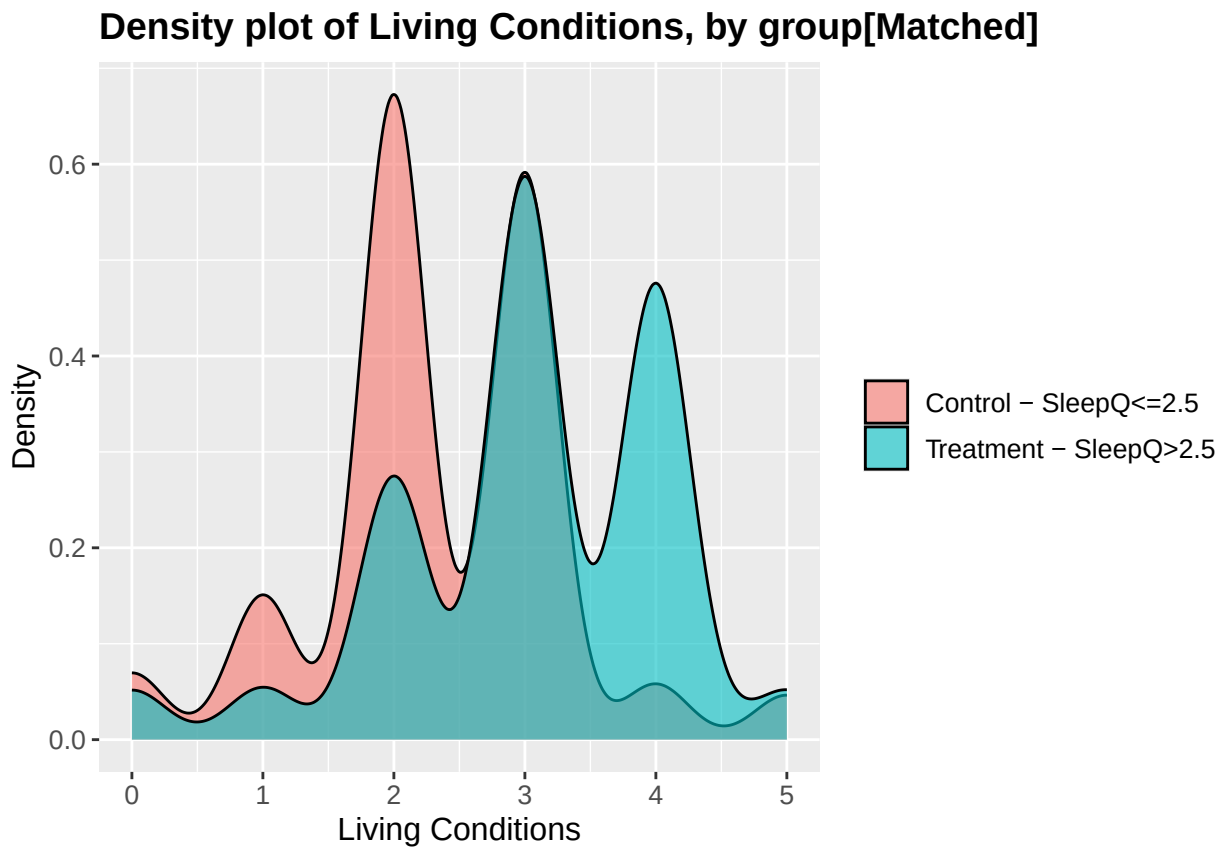



```
ggplot(m_caliper_df, aes(x = m_caliper_df$living_conditions,
    fill = factor(m_caliper_df$sleep_quality_treatment))) + geom_density(position =
    ↪  "identity",
    alpha = 0.6) + scale_fill_brewer(palette = "Dark2") + ggtitle("Density plot of Living
    ↪  Conditions, by group[Matched]") +
    scale_x_continuous(name = "Living Conditions") + scale_y_continuous(name = "Density")
    ↪  +
    theme(plot.title = element_text(size = 14, face = "bold"),
        text = element_text(size = 12)) + guides(fill = guide_legend(title = NULL)) +
    scale_fill_discrete(labels = c("Control - SleepQ<=2.5", "Treatment - SleepQ>2.5"))
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
## Warning: Use of `m_caliper_df$living_conditions` is discouraged.
## i Use `living_conditions` instead.
```

```
## Warning: Use of `m_caliper_df$sleep_quality_treatment` is discouraged.
## i Use `sleep_quality_treatment` instead.
```



6 ATE

6.1 without replacement

```
t.test(m_without_replacement_df$stress_level[m_without_replacement_df$sleep_quality >
    2.5][1:137],
    ↪  m_without_replacement_df$stress_level[m_without_replacement_df$sleep_quality <=
    2.5][1:137])
```

```
##
##  Welch Two Sample t-test
##
## data:  m_without_replacement_df$stress_level[m_without_replacement_df$sleep_quality > 2.5][1:137] and
## t = -16.164, df = 269.72, p-value < 2.2e-16
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -1.2691936 -0.9935801
## sample estimates:
## mean of x mean of y
## 0.4452555 1.5766423
```

```r
model_ate_no_repl <- lm(stress_level ~ sleep_quality_treatment,
    data = m_without_replacement_df)
summary(model_ate_no_repl)
```

```
##
## Call:
## lm(formula = stress_level ~ sleep_quality_treatment, data = m_without_replacement_df)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -1.5400 -0.4527 -0.4527  0.4600  1.5473
##
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)                1.54000    0.02627   58.61   <2e-16 ***
## sleep_quality_treatment -1.08727    0.03716  -29.26   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.6162 on 1098 degrees of freedom
## Multiple R-squared:  0.4381, Adjusted R-squared:  0.4376
## F-statistic: 856.2 on 1 and 1098 DF,  p-value: < 2.2e-16
```

We see the treatment group : people with sleep quality >2.5 have a mean stress level of 0.45 and the control group has a mean stress level of 1.6, which is significantly high. Also the intercept in 1.1 units lower for our treatment group.

6.2 with replacement

```r
t.test(m_with_replacement_df$stress_level[m_with_replacement_df$sleep_quality >
    2.5][1:137], m_with_replacement_df$stress_level[m_with_replacement_df$sleep_quality
    ↪  <=
    2.5][1:137])
```

```
##
##  Welch Two Sample t-test
##
## data:  m_with_replacement_df$stress_level[m_with_replacement_df$sleep_quality > 2.5][1:137] and m_wi
## t = -8.8317, df = 264.81, p-value < 2.2e-16
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.7319799 -0.4651003
## sample estimates:
## mean of x mean of y
## 0.4452555 1.0437956
```

```r
model_ate_repl <- lm(stress_level ~ sleep_quality_treatment,
    data = m_with_replacement_df)
summary(model_ate_repl)
```

```
##
## Call:
## lm(formula = stress_level ~ sleep_quality_treatment, data = m_with_replacement_df)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -1.0438 -0.4527 -0.4527  0.5473  1.5473
##
## Coefficients:
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)               1.04380    0.05141   20.30   <2e-16 ***
## sleep_quality_treatment -0.59107    0.05745  -10.29   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.6017 on 685 degrees of freedom
## Multiple R-squared:  0.1338, Adjusted R-squared:  0.1326
## F-statistic: 105.8 on 1 and 685 DF,  p-value: < 2.2e-16
```

We see the treatment group : people with sleep quality >2.5 have a mean stress level of 0.45 and the control group has a mean stress level of 1.1, which is significantly high. Also the intercept in 0.6 units lower for our treatment group.

6.3 with caliper

```
t.test(m_caliper_df$stress_level[m_caliper_df$sleep_quality >
    2.5][1:137], m_caliper_df$stress_level[m_caliper_df$sleep_quality <=
    2.5][1:137])
```

```
##
##  Welch Two Sample t-test
##
## data:  m_caliper_df$stress_level[m_caliper_df$sleep_quality > 2.5][1:137] and m_caliper_df$stress_lev
## t = -8.8317, df = 264.81, p-value < 2.2e-16
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.7319799 -0.4651003
## sample estimates:
## mean of x mean of y
## 0.4452555 1.0437956
```

```
model_ate_caliper <- lm(stress_level ~ sleep_quality_treatment,
    data = m_caliper_df)
summary(model_ate_caliper)
```

```
##
## Call:
## lm(formula = stress_level ~ sleep_quality_treatment, data = m_caliper_df)
##
## Residuals:
```

```
##     Min      1Q  Median      3Q     Max
## -1.0438 -0.4527 -0.4527  0.5473  1.5473
##
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)                1.04380    0.05141   20.30   <2e-16 ***
## sleep_quality_treatment -0.59107    0.05745  -10.29   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.6017 on 685 degrees of freedom
## Multiple R-squared:  0.1338, Adjusted R-squared:  0.1326
## F-statistic: 105.8 on 1 and 685 DF,  p-value: < 2.2e-16
```

We see the treatment group : people with sleep quality >2.5 have a mean stress level of 0.45 and the control group has a mean stress level of 1, which is significantly high. Also the intercept in 0.6 units lower for our treatment group.

7 Conclusion

From the above analysis we can show that sleep does causally affect stress levels. Lower sleep quality causes higher stress levels.